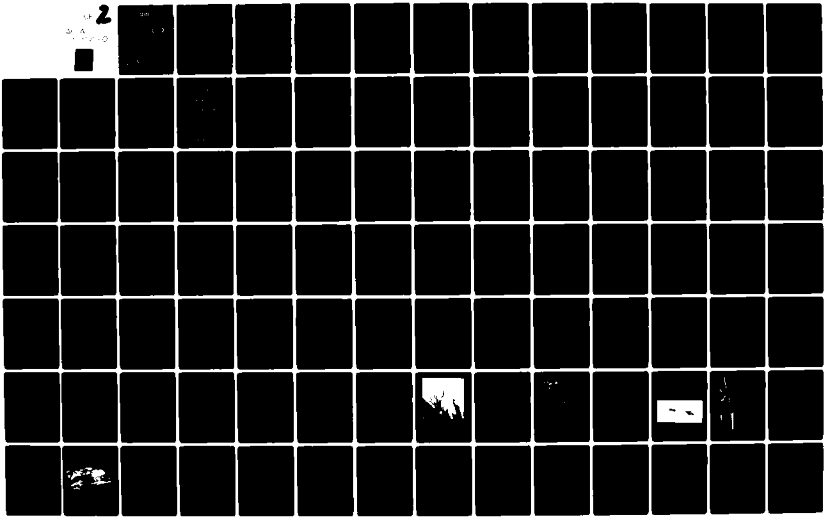
AD-A091 240 ANACAPA SCIENCES INC SANTA BARBARA CA F/G 8/2
TOPOGRAPHIC INFORMATION REQUIREMENTS AND COMPUTER-GRAPHIC DISPL--ETC(U)
DEC 79 S P ROGERS, K D CROSS DAHC19-78-C-0012
UNCLASSIFIED AS-365-79 USAAVRADCOM-TR-78-0012-F NL



LEVEL II

(2)

TOPOGRAPHIC INFORMATION REQUIREMENTS AND COMPUTER-GRAPHIC DISPLAY TECHNIQUES FOR NAP-OF-THE EARTH FLIGHT

Submitted to:

DEPARTMENT OF THE ARMY
U.S. ARMY RESEARCH INSTITUTE FOR THE
BEHAVIORAL AND SOCIAL SCIENCES
Field Unit (PERI-OA)
Fort Rucker, Alabama

and

ADVANCED SYSTEMS DIVISION
U.S. ARMY AVIONICS R&D ACTIVITY
Fort Monmouth, New Jersey

December 1979

ANACAPA SCIENCES, INC.
P. O. DRAWER Q.
SANTA BARBARA, CA 93102
TELEPHONE (805) 966-6157

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (19) USA AVRADCOM TR-78-0012-F	2. GOVT ACCESSION NO. AD-A091	3. RECIPIENT'S CATALOG NUMBER 240 (9)
4. TITLE (and Subtitle) (6) TOPOGRAPHIC INFORMATION REQUIREMENTS AND COMPUTER-GRAPHIC DISPLAY TECHNIQUES FOR NAP-OF-THE-EARTH FLIGHT.		5. TYPE OF REPORT & PERIOD COVERED Annual Technical Report, Jan-Dec 1979
	(14) AS-	6. PERFORMING ORG. REPORT NUMBER 365-79
7. AUTHOR(s) (10) Steven P. Rogers and Kenneth D. Cross	(15)	8. CONTRACT OR GRANT NUMBER(s) DAHC19-78-C-0012
9. PERFORMING ORGANIZATION NAME AND ADDRESS ANACAPA SCIENCES, INCORPORATED P.O. Drawer Q Santa Barbara, CA 93102		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (17) 2Q162717A790 8A 002
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Avionics R&D Activity Advanced Systems Division (DAVAA-F) Fort Monmouth, New Jersey 07703	(11)	12. REPORT DATE December 1979
		13. NUMBER OF PAGES 96
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) US Army Research Institute for the Behavioral and Social Sciences Field Unit (PERI-OA) Fort Rucker, Alabama 36362	(12) 101	15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release. Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Army Aviation	Geography & Orientation (Direction)	Navigation
Computers Display Systems	Human Factors Engineering	
Computer Graphics	Information & Requirements	
Display Systems	Mapping	
Flight and Low-level	Planning & Tactical Warfare	Topography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a study undertaken to identify tasks required of Army aviators performing terrain flight, and to determine the ways in which a computer-generated topographic display might aid in the conduct of these tasks.

The report provides:

(a.) An inventory of the full range of preflight and inflight tasks performed by the Army aviator that require the use of map products, overlays, and geographi

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

405 7 L

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. continued.

data.

b. A review of the recent developments and state-of-the-art in computer graphics technology that are applicable to the production of map products and related displays.

c. Descriptions of computer-graphic capabilities that have potential value for the conduct of flight planning, the conduct of navigation, and the accomplishment of related tasks.

TOPOGRAPHIC INFORMATION REQUIREMENTS AND COMPUTER-GRAPHIC DISPLAY TECHNIQUES FOR NAP-OF-THE-EARTH FLIGHT

Steven P. Rogers
and
Kenneth D. Cross

Submitted to:

DEPARTMENT OF THE ARMY
U.S. Army Research Institute for the Behavioral and Social Sciences
Field Unit (PERI-OA)
Fort Rucker, Alabama 36362

and

U.S. ARMY AVIONICS R&D ACTIVITY
Advanced Systems Division (DAVAA-F)
Fort Monmouth, New Jersey 07703

Submitted by:

ANACAPA SCIENCES, INCORPORATED
P.O. Drawer Q
Santa Barbara, California 93102

December 1979

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION

This report describes a study undertaken to identify tasks required of Army aviators performing terrain flight, and to determine the ways in which a computer-generated topographic display might aid in the conduct of these tasks. The study was executed under Contract DAHC19-78-C-0012, Modification No. P00002 for the U. S. Army Research Institute for the Behavioral and Social Sciences, and for the Advanced Systems Division of the U. S. Army Avionics Research and Development Activity.

BACKGROUND

Army aviation units are expected to make a major contribution to the Combined Arms Team in land combat in the high-threat environment. Army helicopters are suited not only for destroying enemy point targets for ground forces, but for efficiently transporting combat units, and for envelopment, penetration, exploration, and pursuit operations. Whatever the combat task, the Army aviator must be able to maintain his geographic orientation at all times. Aviators must be able to plan and execute their missions precisely in both time and space and relate their momentary position to their planned route and to the movements of other friendly ground and air forces. In the critical timing of events on the modern battlefield, disorientation is tantamount to mission failure. As a minimum standard, Army aviators are expected to navigate to an accuracy of 100 meters at all times (FM 1-1). Furthermore, aviators are expected to navigate in unfamiliar terrain, around-the-clock, and in adverse weather conditions.

These navigation requirements are stringent ones even for aircraft flying at altitudes well above the terrain. Survival in the high-threat environment, however, depends upon the conduct of nap-of-the-earth (NOE) flight: flight as close to the earth's surface as vegetation and obstacles will permit in order to use a weaving and devious route while take advantage

of the cover and concealment provided by landforms, vegetation, and man-made features. While low-level navigation may be conducted by periodically identifying successive checkpoints, NOE navigation demands continuous correlation of features depicted on the map with those features detected and identified in the surrounding terrain.

The likelihood of geographic disorientation is greatly increased during NOE flight due to the aviator's limited view of checkpoint features useful in navigation and to a shortage of optimal map products. While NOE flight serves to mask the enemy's view of the helicopter, it often masks the aviator's view of potential checkpoints. The view of the surrounding terrain may be limited to features within 100 meters of the aircraft. Features often cannot be seen in their entirety, and the extremely low angle of view increases the difficulty of determining the contours of visible landforms. The geographic orientation task is even more difficult if maps are not current, or are unavailable in the large (1:50,000) scale needed for NOE use. Since map compilation and production requires months (under routine priority) and hundreds of thousands of 1:50,000-scale maps would be required to depict the earth's surface, it is evident that large-scale maps cannot be kept current for all possible combat areas. Up-to-date 1:50,000-scale maps are available for only small portions of the earth's surface. Should a conflict erupt in an area for which optimal maps were temporarily unavailable, the probability of disorientation during NOE flight would be further escalated.

In addition to the navigation requirements, extensive mission planning activities are required of the Army aviator. The successful accomplishment of many of these activities depends upon the aviator's ability to extract information from maps. For example, the aviator must study and visualize the overall situation and topography; select engagement points, observation points, or landing zones; determine primary and alternate (masked) routes of flight; select air control points, checkpoints, and barrier features; and determine flight modes, altitudes, speeds, and durations. Each of these activities places an onerous information compilation and processing demand upon the aviator, and omissions or errors might well prove to be disastrous.

The emerging technology of computer-generated topographic display systems offers potential solutions to many of the problems of NOE flight planning and navigation. A primary virtue of such a system is that the data required to support a computer-generated topographic display could be obtained and processed for any area of interest in a relatively short time, thus permitting the portrayal of areas for which conventional large-scale maps are available. In addition, a computer-generated topographic display could aid the aviator by helping him to tailor his "map" to the momentary NOE requirements, to change map scale, to select contour interval, to define feature selection rules as appropriate, and to perform a number of valuable calculations. Furthermore, such a system is especially compatible with a terrain correlation navigation system which is small and lightweight, is accurate in all weather, is self-contained, and is essentially invulnerable to countermeasures.

The U. S. Army Avionics R&D Activity is actively investigating the feasibility of a computer-generated topographic display system and is currently performing preliminary design studies in support of such a system. The typical phases of system development are shown in Figure 1. This figure graphically portrays the present and future phases of development, and shows the five categories of inputs required to perform preliminary design activities. The project described in this report was conducted to aid in definition of system functions and technological options. In this context, system functions are the display and processing of map-related information. Technological options include the computer-based techniques that would allow these functions to be performed more efficiently than ever before.

PROJECT OBJECTIVES

The general objective of this project was to optimize the preliminary design of a topographic display by identifying processes currently performed by the aviator that could be performed by a computerized system more swiftly, more accurately, or both. The specific objectives were to:

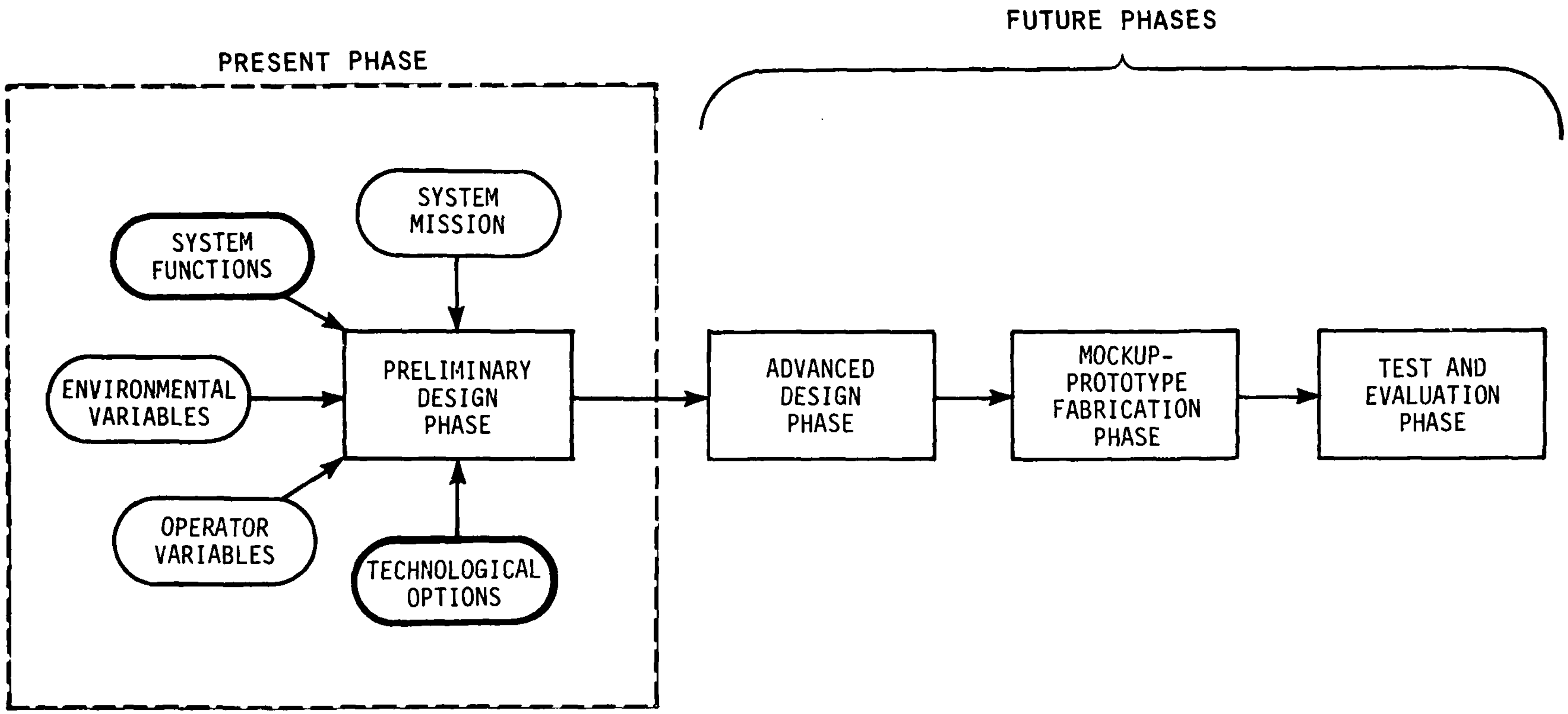


Figure 1. Phases of system development. Inputs to the preliminary design phase dealt with in this report are indicated by bold-lined ovals.

- Inventory the full range of preflight and inflight tasks performed by the Army aviator that require the use of map products, overlays, and geographic data.
- Review the recent developments and state-of-the-art in computer graphics technology that are applicable to the production of map products and related displays.
- Determine computer-graphic capabilities that have potential value for the conduct of flight planning, the conduct of navigation, and the accomplishment of related tasks.

PROJECT APPROACH

The approach to the identification of aviator tasks was one of literature review, supplemented by observation and interview of NOE-qualified pilots. The primary documents employed were the following:

Gainer, C. A., and Sullivan, D. J. *Aircrew training requirements for nap-of-the-earth flight.* Santa Barbara, California: Anacapa Sciences, Inc., May 1974.

Garlichs, E. A., Cox, R., Hockenberger, R. L., and Smith, B. A. *Tactical permission planning.* Fort Rucker, Alabama: Canyon Research Group/Army Research Institute, June 1979 (draft edition).

U. S. Army. *FM 1-1, Terrain flying.* October 1976.

U. S. Army. *FM 17-50, Attack helicopter operations.* July 1977.

U. S. Army. *FM 90-1, Employment of aviation units in a high threat environment.* September 1976.

The information acquired from these documents was supplemented by observation of pilots conducting NOE flight in a variety of terrain types, and by informal interviews with NOE-qualified pilots. The findings are summarized in tabular form in Section II of this report.

The approach to the identification of useful computer-graphic techniques also began with a literature review. It soon became apparent, however, that the field is in the throes of rapid technological changes in which development is outpacing the ability to document the emerging capabilities. As a result, the research approach was amended to include interviews with experts in the computer graphics field. Telephone interviews were conducted with 22

individuals recognized for their experience in the acquisition, processing and display of digital topographic data. Subsequent face-to-face interviews were arranged with 18 of these individuals in order to discuss in greater depth recent developments in their areas of expertise. The following experts and their organizations are gratefully acknowledged:

CPT George Buckland, U. S. Air Force Human Resources Laboratory
Mr. Howard Carr, U. S. Army Engineer Topographic Laboratory
CPT John Charland, U. S. Military Academy, West Point
Dr. Craig Fields, Defense Advanced Research Projects Agency
LTC Donald Fisch, Defense Mapping Agency
Mr. Cliff Godwin, Honeywell Marine Systems Division
MAJ Gene Hazel, Defense Mapping Agency
Mr. James Jancaitis, U. S. Army Engineer Topographic Laboratory
Dr. Victor La Garde, U. S. Army Engineer Waterways Experiment Station
Mr. Frank Lewandowski, Singer, Link Division
Mr. Jeff Neal, General Electric Company
Mr. Warren Olsen, U. S. Army Tradoc Systems Analysis Division
Mr. Michael Paradis, Defense Mapping Agency
Dr. Larry Pfortmiller, Combined Arms Combat Development Activity
Dr. Zita Simutis, Army Research Institute
LTC Ronald Sorontino, Defense Mapping Agency
Dr. Sterling Stackhouse, Minneapolis-Honeywell
Dr. Louis Tamburino, U. S. Air Force Avionics Laboratory
Mr. Richard Vitek, Defense Mapping Agency
Dr. Gershon Weltman, Perceptronics, Inc.
Mr. George Whitley, Electromagnetic Compatibility Analysis Center
Dr. Lee Williams, Minneapolis-Honeywell

On-site visits were made to six of these agencies in order to view demonstrations of digital topographic display systems:

Engineer Topographic Laboratory
Combined Arms Combat Development Activity
Minneapolis-Honeywell
Singer-Link Division
Defense Advanced Research Projects Agency
U.S. Military Academy, West Point

The computer-graphic techniques found to be particularly applicable to topographic display systems are discussed in Section IV.

ORGANIZATION OF THE REPORT

This report is organized to be used as a compendium of design data. Each of the succeeding three sections presents a category of information that will be useful in generating and evaluating design specifications for a computer-generated topographic display.

Section II, Army Aviator Tasks and Information Requirements, identifies the range of functions required for helicopter mission performance, and for each function, defines the specific information items required by the Army aviator. This data is presented in tabular form in pages color-coded for easy reference.

Section III, Specific Topographic Information Requirements, identifies the subset of information items required by the Army aviator that can only be presented through the use of maps, overlays, and related products. Each of the information items identified in this section must be considered during the design of a computer-generated topographic display system. These requirements are provided in tabular form and, like those of Section II, are color-coded for the reader's convenience.

Section IV, Key Features for a Computer-Generated Topographic Display, describes four categories of display functions afforded by computer-graphic techniques that would be likely to enhance the efficiency of mission conduct. The information presented in this section is not intended to comprise a comprehensive set of design recommendations, but describes a number of potentially valuable features identified during the review of recent developments in computer graphics. This section of the report discusses the nature of the information-processing tasks demanded of the Army aviator, the special problems encountered in performing these tasks, and the state-of-the-art techniques which could be applied to unburden the aviator and to provide him with topographic information in the form that best meets his momentary needs.

SECTION II

ARMY AVIATOR TASKS AND INFORMATION REQUIREMENTS

The U. S. Army currently employs six different types of helicopters to perform the variety of missions imposed on them. The types of helicopters include the following:

- UH-1H UTILITY
- OH-58 SCOUT
- AH-1G/R ATTACK
- AH-1Q/S COBRA TOW
- CH-47C ASSAULT SUPPORT
- CH-54 HEAVY

These helicopter types are used by one or more of the following Army aviation units:

- AIR CALVARY TROOP/SQUADRON
- ATTACK HELICOPTER COMPANY/BATTALION
- AIR CALVARY COMBAT BRIGADE
- ASSAULT HELICOPTER COMPANY/BATTALION
- ASSAULT SUPPORT HELICOPTER COMPANY/BATTALION
- HEAVY HELICOPTER COMPANY
- DIVISION AVIATION COMPANY
- AVIATION COMPANY GENERAL SUPPORT
- AVIATION SECTION, DIVISION ARTILLERY
- BRIGADE AVIATION SECTION

In recent years, there has been an enormous increase in the capabilities of the helicopters, and a similar increase in the types of missions that may now be required of the Army aviator. A few examples include the following:

- INTELLIGENCE GATHERING
- ANTI-ARMOR OPERATIONS
- RAIDS ON ENEMY FLANKS

- COMBINED ARMS OPERATIONS
- REINFORCEMENT
- TROOP TRANSPORT
- BLOCKING ENEMY FORCES
- SUPPLY MOVEMENT
- ADJUSTING ARTILLERY FIRE
- COMMAND AND CONTROL
- AEROMEDICAL EVACUATION
- BATTLEFIELD ILLUMINATION
- BRIDGE CONSTRUCTION
- MINE EMPLACEMENT
- EXPLOITATION
- QUICK-REACTION OPERATIONS

Despite the number and diversity of aircraft types, aviation units, and required missions, the mission planning and navigation tasks are similar in nearly all respects. Regardless of the specific objective of the flight, there are certain tasks that aviators always must perform, such as selecting the route of flight and maintaining geographic orientation. Consequently, while the information requirements analysis described below is based primarily on the activities of an attack aircraft, it can be considered representative of most Army helicopter missions.

A summary of the mission phases for the attack helicopter is shown in Figure 2. Each of the six phases is composed of one or more segments. The segments which require the use of a map or map-related product are indicated by the presence of a black dot. The nine segments so indicated were further subdivided into the functions required within that segment. The phases, segments, and functions requiring the use of map products are outlined in Table 1.

The functions identified in Table I were analyzed to determine the information items required for the performance of each function. These information requirements were elaborated further by identifying the specific types of data required and the typical sources of these data. The results of this analysis are described fully in the following color-coded pages.

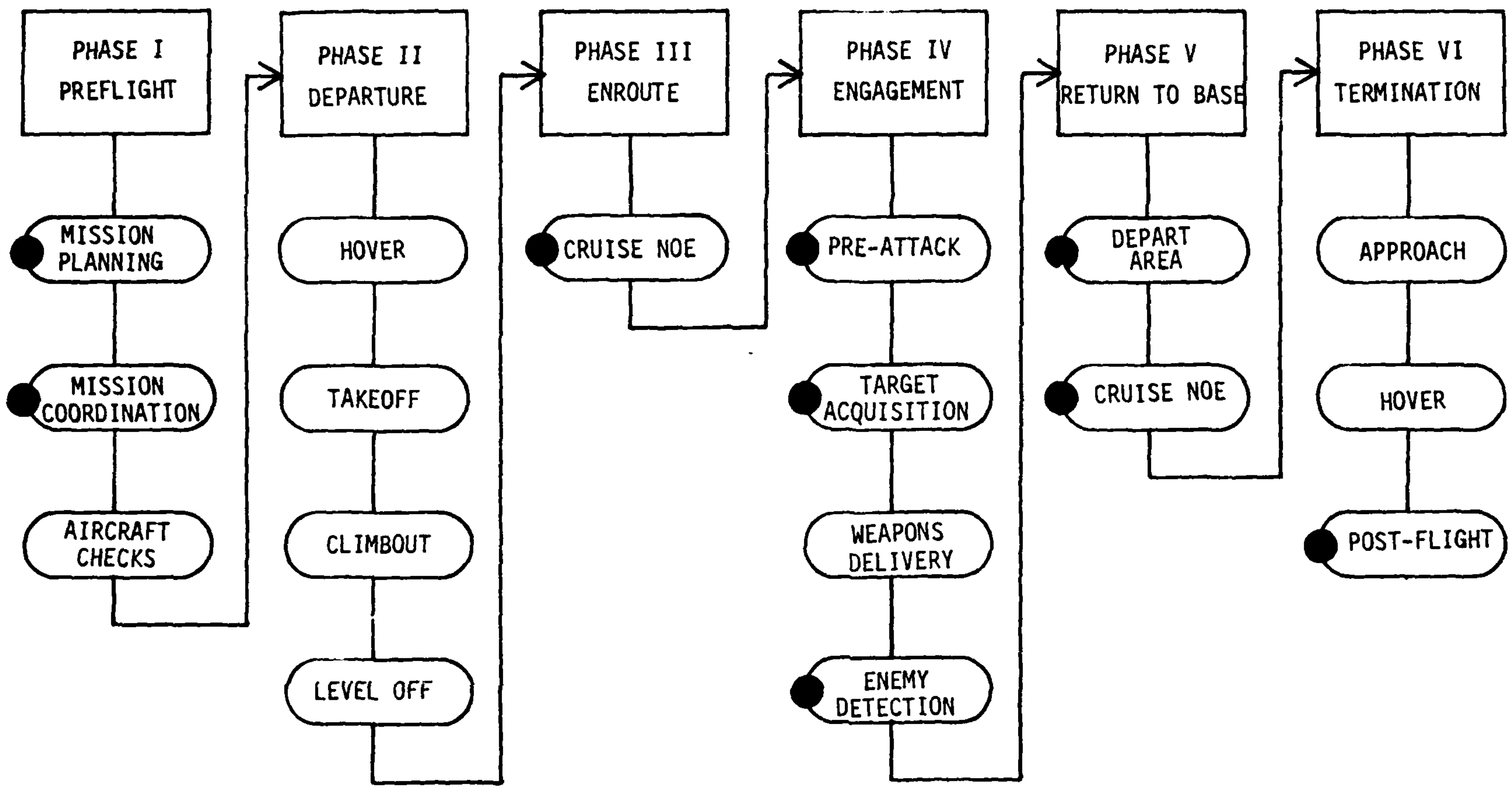


Figure 2. Summary of mission phases for the attack helicopter. Dots indicate map usage requirement.

TABLE I.

SUMMARY OF PHASES, SEGMENTS, AND FUNCTIONS REQUIRING MAP USAGE

PHASE	SEGMENT	FUNCTION
I. PREFLIGHT	A. Mission Planning	IA1 Receive Operations Order IA2 Obtain Supplementary Information IA3 Acquire Maps, Photos, Overlays IA4 Perform Map and Aerial Photo Study (Analyze Situation & Topography) IA5a Select Battle Positions (Attack Aircraft) IA5b Select Aerial Observation Positions (Scout) IA5c Select Landing Zone (Utility) IA6 Determine Primary and Alternate Routes of Flight IA7 Determine Air Control Points, Checkpoints, and Barriers IA8 Annotate Map, Overlay, Flight Log IA9 Determine Modes of Flight and Maximum Flight Altitudes IA10 Determine Airspeeds IA11 Calculate Time Estimates IA12 Determine Fuel Requirements IA13 Select Armament & Special Equip. IA14 Coordinate Fire Support IA15 Conduct Contingency Planning IA16 Final Weather Check
	B. Mission Coordination	IB1 Brief Crew IB2 Brief Passengers (Utility)
III. ENROUTE	A. Cruise NOE	IIIA1 Determine Position IIIA2 Crew Coordination (Topographic) IIIA3 Radio Communication
IV. ENGAGEMENT	A. Pre-Attack	IVA1 Arrive Battle Position, AOP, LZ IVA2 Perform Visual Observation (Recon)
	B. Target Acquisition	IVB1 Receive Target Data IVB2 Perform Visual Search
	D. Enemy Detection	IVD1 Maneuver to New AOP/Battle Position
V. RETURN TO BASE (STAGING AREA)	A. Depart Maneuver Area	VA1 Determine Return Route
	B. Cruise NOE	VB1 Determine Position VB2 Crew Coordination (Topographic) VB3 Radio Communication
VI. TERMINATION	C. Post-Flight	VIC1 Debriefing

TABLE II.

INFORMATION REQUIRED BY ARMY AVIATORS
FOR PLANNING AND CONDUCTING MISSIONS

PHASE I: PREFLIGHT SEGMENT A: MISSION PLANNING

FUNCTION: IA1 RECEIVE OPERATIONS ORDER

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
SITUATION	A. Enemy Forces: 1) Disposition 2) Strength 3) Capability 4) Probable Course of Action	G2/S2 with operation overlay	A Fragmentary Order (FRAGORD) or oral order may be issued in place of the standard Operations Order (OPORD).
	B. Friendly Forces: 1) Disposition 2) Strength 3) Course of Action	OPNS Officer with operation overlay	
	C. Attachments and Detachments		
MISSION	Who What When Why Where	Higher HQ and Unit Commander with operation overlay	Examples: Reconnaissance Recon with engagemen Escort Troop support Anti-armor Aerial arty Medivac
EXECUTION	Concept of Operation: Scheme of Maneuver Fire Support Operation Phasing Other, as required	Unit Commander with operation overlay	"How"
SERVICE SUPPORT	Fuel Location Armament Location Ammunition Loads Maintenance Reqmts Other, as required	Unit Commander with operation overlay	
COMMAND AND SIGNAL	Radio Call Signs Frequencies Procedures	Current Index to Communications-Electronics Operating Instructions (CEOI) Unit SOP	
	Change of Command Location of Division Command Post and Axis of Displacement	Unit Commander with operation overlay	

FUNCTION: IA2 OBTAIN SUPPLEMENTARY INFORMATION

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
A. INTELLIGENCE			
ENEMY FORCES	Aircraft Anti-Aircraft Weapons Missiles Detection Capability Lock-on Ranges "Shot-at" Reports	Intelligence Annex, Periodic Intelligence Report, Intelligence Summary Operations Map Briefings Other Pilots	Amount of information in OPORD varies
FRIENDLY FORCES	Next Higher Unit Adjacent Units Supporting Units: Reserve Force Field Artillery Air Defense Artillery Others	Operations Officer Briefings Operations Map	Locations and posture of friendly supporting or supported units must be known
CONDITIONS	Electronic Warfare	Meaconing, Intrusion, Jamming and Interference (MIJI) Report Operations Map	MIJI may not be available due to security classificatio
	Nuclear, Biological, or Chemical (NBC) Contamination	Operations Map	
B. COMMUNICATIONS	Radio Masking	Construct Terrain Profiles along Route of Flight to Determine Transmission Possibilities	Prearrange signals to be used as aircraft passes points from which transmissions are possible
	Visual Signals	CEOI and Unit SOP	
C. WEATHER	At Takeoff Enroute Destination and Alternates	Operations Officer	Wind speed and direction, ceiling, horizontal visibility needed

FUNCTION: IA3 ACQUIRE MAPS, PHOTOS, OVERLAYS

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
MAPS AVAILABLE		Operations Officer	
BEST PLANNING MAPS	Scale Contour Interval Type Age Grid Other		
BEST INFLIGHT MAPS	Scale Contour Interval Type Age Grid Other		
AERIAL PHOTOS	Vertical Low Oblique High Oblique	Operations Officer	Useful to check for recent changes or visual checkpoints not shown on map
OVERLAYS .	Engineer Reports "Shot-at" Reports Friendly Force Boundaries Hazards to Flight Other, as required	Operations Officer	

FUNCTION: IA4 PERFORM MAP AND AERIAL PHOTO STUDY (ANALYZE SITUATION AND TOPOGRAPHY)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
GENERAL OVERVIEW	Hostile Areas Friendly Areas High and Low Ground Populated Areas Battle Area Boundaries	Prior Briefing Map and Photos	Map is annotated from prior briefing
COORDINATES FOR PLOTTING SITES AND AREAS	Ambush Sites Firing Positions Landing Zones Air Control Points (ACP's) Forward Edge of the Battle Area (FEBA) Known Enemy Positions Suspected Enemy Positions Assembly Areas Friendly CP's, GOP's Holding Areas FARRP's Other	Briefing	Accuracy to nearest six-digit coordinate is required when plotting Position of enemy radar sites particularly important
PROMINENT TOPOGRAPHIC FEATURES	Key Terrain Flight Hazards Open Areas Vegetation Patterns Ridgelines Drainage Features Major Cultural Features	Map and Photos	Key terrain is usually that providing good observation

FUNCTION: IA5a SELECT BATTLE POSITIONS (ATTACK AIRCRAFT)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
TARGET	Type Capabilities Location	Briefing/Map	
SITUATION	Enemy Situation Friendly Situation	Briefing/Map	
DISTANCE	Maximum Weapon Standoff Range	Reports	
MASKING	Cover and Concealment at Battle Positions	Map/Scout	Must have line-of-sight to target when unmask
	Concealment of Approach Routes	Map	

FUNCTION: IA5b SELECT AERIAL OBSERVATION POSITIONS (SCOUT)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
RECONNAISSANCE TASK	Type of Information Sought, such as Troop Movements, Tank Positions, ADA Locations, etc.	OPORD	
SITUATION	Enemy Situation Friendly Situation	Briefing/Map	
DISTANCE	Maximum Practical Observation Distance	Aviator Knowledge	
MASKING	Cover and Concealment at Observation Positions	Map	
	Concealment of Approach Routes	Map	

FUNCTION: IA5c SELECT LANDING ZONE (UTILITY)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
UTILITY TASK	Raid, Resupply, Reinforcement, Medivac, Etc.	OPORD	
SITUATION	Enemy Situation Friendly Situation	Briefing/Map	
OBSTACLES	Obstacles to Landing Obstacles to Approach		
SIZE	Necessary Open Area	Aviator Knowledge	
MASKING	Cover and Concealment at LZ	Map	
	Concealment of Approach Routes	Map	

FUNCTION: IA6 DETERMINE PRIMARY AND ALTERNATE ROUTES OF FLIGHT

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
ANALYSES OF AVENUES OF APPROACH:			Primary and alternate routes chosen by same criteria
COVER	Vegetation or Terrain Providing Protection From Fire (Defilade)	Map	
CONCEALMENT	Protection From Observation by Terrain, Vegetation, Etc.	Map	Avoid open areas; avoid silhouetting when crossing ridgelines
OBSERVATION	Terrain Influence on Visual, Optical, and Electronic Surveillance	Map	High ground usually offers best observation (key terrain)
VISIBILITY	Weather Influence on Surveillance	OPNS Officer	
FIELDS OF FIRE	Terrain Influence on Direct and Indirect Fire	Map	
EASE OF MOVEMENT	Length and Directness of Route and Adequacy of Maneuver Space Forced Landing Areas Avoidance of Friendly Artillery Surface Wind Info.	Map OPNS Officer	
EASE OF NAVIGATION	Familiar Terrain and/or Available Air Control Points, Checkpoints, and Barrier Features	Map	Navigation Accuracy is expected to be within 100 meters. Avoid following man-made linear features
POSITION OF SUN OR MOON	Avoid Flying into Sun or Moon if Possible	Map/Aviator Knowledge	

FUNCTION: IA7 DETERMINE AIR CONTROL POINTS, CHECKPOINTS, AND BARRIERS

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
AIR CONTROL POINT AND CHECKPOINT SELECTION	Availability	Map/Aviator Knowledge	ACP's are critical points along route, such as turning points. Checkpoints are "on-course" indicators 2-5 minutes apart. Avoid use of man-made objects as checkpoints.
	Perceptability (visual prominence) from NOE Altitude	Map/Aviator Knowledge	
	Discriminability (uniqueness)	Map/Aviator Knowledge	
	Reliability of Mapped Feature Presence in Real World	Map/Aviator Knowledge	
	Enemy Awareness of Likely Checkpoints	Map/Aviator Knowledge	
BARRIER FEATURES	Linear (roads, rivers, etc.) Funnel (convergence of linears) Point (good vertical development) Time (add 2-5 minutes)	Map	Barrier features prevent greatly over-flying turning points or objective.

FUNCTION: IA8 ANNOTATE MAP, OVERLAY, FLIGHT LOG

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
MAP OR OVERLAY ANNOTATIONS		Sources of all items are identified elsewhere in this analysis	Security reasons may prohibit annotation with some items. See unit SOP.
	Course Lines Air Control Points Magnetic Headings Time or Mileage Tic Marks Mode of Flight Changes Hazards to Flight Boundaries Flight Corridors Barrier Features Key Point Elevations Checkpoints Enemy Forces Friendly Forces Radio Transmission Points FEBA FARRPS Phase Lines LZ's, Battle Positions Holding Areas Radio Nav Aids Preplanned Artillery Targets Rally/Pickup Points		
LOG ANNOTATIONS	Altitudes Airspeeds Time Estimates Fuel Requirements Fire Support Radio Call Signs Radio Frequencies Weather Command Information		Often many of the map annotation items are noted instead in the log to reduce map clutter.

FUNCTION: IA9 DETERMINE MODES OF FLIGHT AND MAXIMUM FLIGHT ALTITUDES

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
ENEMY SITUATION	Proximity Radar Capability AA Weapons	OPNS Officer	
FLIGHT ROUTE	Spot Elevations Index Contours Intermediate Contours Vegetation Type Obstacles	Map	
COVER AND CONCEALMENT COMPUTATIONS	Maximum Permissible Altitude at any Given Point Along Route Which Provides Masking From Enemy Observation and Fire	Map/Aviator Knowledge	If masking not possible, dash mode will be employed.
TIME CONSIDERATIONS (MISSION URGENCY)	Required Number of Sorties Per Unit Time Required Distance of Sorties Per Unit Time	OPNS Officer	If masking terrain is available, low-level or contour flight are preferable. given their higher airspeeds.
WEATHER	Reduced Visibility to Interfere with Visual Contact with Ground	OPNS Officer	
			Enter maximum altitudes for each leg of route in flight log. Annotate map with changes in mode of flight (low level, contour, and NOE).

FUNCTION: IA10 DETERMINE AIRSPEEDS

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
DISTANCES	Length of Each Leg From Staging Area to Objective and Return	Annotated Map	
TERRAIN	Features Affecting Airspeed, Such as Slopes, Altitude	Map	
WEATHER	Conditions Affecting Airspeed Such as Fog	OPNS Officer	
AIRCRAFT	Gross Weight and Performance Data for Conditions	Reports/Aviator Knowledge	
FLIGHT MODE	NOE Contour Low-Level Dash	Aviator Decision	
MISSION CONSTRAINTS	Special Timing Requirements	OPNS Officer/OPORD	
			Enter airspeeds in flight log.

FUNCTION: IA11 CALCULATE TIME ESTIMATES

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
OBJECTIVE ARRIVAL TIME	Mission Engagement Point Arrival Time	Operations Order	±60 second accuracy may be required.
CHECKPOINT TIMES	Enroute Times for Each Leg of Flight (Between Air Control Points) and Between Each Checkpoint Pair	Distance (from map) and Airspeed Computations	
ENROUTE TIME	Time From Staging Area to Objective	Add Checkpoint Times	
DEPARTURE TIME	Time to Leave the Staging Area	Arrival Time Minus Enroute Time	Allow time for planning, briefings, aircraft preparation, and checkout.
MISSION TIME	Time Required (or allowed) to Perform Mission	Operations Order	
RETURN TIME	Time From Objective to Staging Area	Add Checkpoint Times	
TOTAL FLIGHT TIME	Time From Departure to Return	Add Enroute, Mission, and Return Times	
FLIGHT TERMINATION TIME	Time of Return to Staging Area	Add Total Flight Time to Departure Time	
			Enter time estimates in flight log.

FUNCTION: IA12 DETERMINE FUEL REQUIREMENTS

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
FLIGHT DISTANCE		Map/Log	
FLIGHT ALTITUDE		Map/Log	
FLIGHT AIRSPEED		Log	
TOTAL FLIGHT TIME		Log	
WIND	Velocity and Direction at Flight Altitude	Briefing	
FUEL REQUIREMENTS	Minimum Required Reserve Maximum Allowed	Computations/Reports	
			Enter fuel computations in flight log.

FUNCTION: IA13 SELECT ARMAMENT AND SPECIAL EQUIPMENT

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
MISSION OBJECTIVE	Primary Targets Secondary Targets	Briefing Data/Map	Locate with accuracy of six-digit coordinate.
EFFECTIVE ARMAMENT (OFFENSIVE)	Rockets Missiles Small Arms	Armament Lists and Aviator Knowledge	Consider target defense capability.
ENEMY THREAT	Ambush Armor Personnel Artillery Other	Map/Briefing Data	
EFFECTIVE ARMAMENT (DEFENSIVE)	Rockets Missiles Small Arms	Armament Lists and Aviator Knowledge	
SPECIAL EQUIPMENT	Mine Dispensers Protective Masks Night Vision Goggles Etc.	OPNS Officer/Aviator	

FUNCTION: IA14 COORDINATE FIRE SUPPORT

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
PREPLANNED TARGETS	Coordinates of Likely Enemy Positions	Map/Overlay/OPORD	
	Code Names of Targets	Aviator/OPNS Officer	
ARTILLERY AIR CORRIDORS	Locations Active Times Artillery Type Priority of Fire	OPNS Officer	Priority is often coded: RED = Fire on all aircraft YELLOW = Fire on positively identified aircraft GREEN = Fire on no aircraft
SUPPORTING UNITS	Suppressive Fire: Artillery Support Priority for your Mission Air Strikes: Attack Helicopters Tactical Aircraft Naval Gunfire Smoke or Chaff	OPNS Officer	If low priority, may not receive desired support.
			Enter fire support data in flight log and on map or overlay.

FUNCTION: IA15 CONDUCT CONTINGENCY PLANNING

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
REVIEW PROCEDURES FOR AIRCRAFT INFLIGHT EMERGENCIES, SYSTEM MALFUNCTIONS, COMMUNICATIONS LOSS, ETC.	As Appropriate	Unit SOP/"Dash 10"	
REVIEW PROCEDURES FOR TACTICAL CONTINGENCIES	As Appropriate	Unit SOP/Map	
REVIEW PROCEDURES FOR ENVIRONMENTAL CONTINGENCIES	As Appropriate	Unit SOP/Map	
PLAN ESCAPE AND EVASION	As Appropriate	FM 21-76/Map	

FUNCTION: IA16 FINAL WEATHER CHECK

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
MOST RECENT WEATHER		OPNS Officer Other Pilots	
EFFECT ON FLIGHT	Lowered Visibility High Density Altitude Winds Icing Other	Briefing, Planned Flight Route (Map) Aviator Knowledge	
			Enter critical weather information in flight log.

PHASE I: PREFLIGHT SEGMENT B: MISSION COORDINATION

FUNCTION: IB1 BRIEF CREW

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
SITUATION	Enemy Situation Friendly Situation Weather EW, NBC Conditions	OPORD/NOTES Map	Recap G2/S2 and OPNS Officer Briefing.
MISSION	As in OPORD Special Problems	OPORD/Notes Map	Recap OPNS Officer briefing.
EXECUTION:			
FLIGHT ROUTE	Entry and Exit, Primary and Alternate Airspeeds and Altitudes	Map and Log	
TERRAIN	Landforms, Vegetation, Drainage, Hazards	Map	
NAVIGATION	Air Control Points Checkpoints Barrier Features	Map and Log	
FIRE SUPPORT	Supporting Units Artillery Naval Tac Air Priorities Preplanned Targets	OPORD/Notes	
COORDINATION	Schedule Critical Timing Events Interaction With Other Units	OPORD/Notes	
CONTINGENCIES	Aircraft Tactical Environmental Escape and Evasion	Unit SOP/Map	
SERVICE SUPPORT	Fuel, Armament Locations, Maintenance Requirements, Rations, Relief, Medivac	OPORD/Notes	
COMMAND AND SIGNAL	Times of Operation Call Signs Radio Frequencies Visual Signals Change of Command Location of Division CP and Axis of Displacement	OPORD/Notes	

FUNCTION: IB2 BRIEF PASSENGERS (UTILITY)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
FLIGHT PLAN	General Route Duration Altitude Landing Zone	Map and Log	
PROCEDURES	Aircraft Entry and Exit Rotor Clearance Emergencies Communication	Checklist	
CONSTRAINTS	Smoking Movement Other	SOP	

PHASE III: ENROUTE SEGMENT A: CRUISE NOE

FUNCTION: IIIA1 DETERMINE POSITION

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
TIME	Minutes From Last Positively Identified Point	Clock	
AIRSPEED	Approximate Average	Airspeed Indicator	NOE flight may require continual changes in airspeed and heading to achieve masking so position deduction is not accurate, but provides a general area for checkpoint search.
HEADING	Approximate Average	Compass	
DEDUCED POSITION	Position Deduced from Time, Airspeed, and Heading	Map/Aviator Knowledge	
CHECKPOINTS	Identify Preplanned Checkpoints	Map/Log	
	Interpret Topographic Map Contour and Symbols	Map/Aviator Knowledge	
	Search Visible Terrain for Features	Aviator Knowledge	
	Correlate Map and Surrounding Terrain	Map/Aviator Knowledge	
	Positively Identify Checkpoints		
RESECTION	Determine Position by Sighting on 2 or 3 Known Features	Compass, Map, Aviator Knowledge	Not necessary if flight is near or over checkpoints. Often not possible from NOE (masked) altitude.
BARRIERS	Features Which Prevent Greatly Overflying Turning Points or Objective: Linear, Funnel, Point, Time	Map/Aviator Knowledge Log	Not necessary unless checkpoints are missed.

FUNCTION: IIIA2 CREW COORDINATION (TOPOGRAPHIC)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
POSITION	Navigator Describes Present Position with Reference to Planned Course, Air Control Points, and Checkpoints	Map/Log, Aviator Knowledge	
NAVIGATION INSTRUCTIONS	Provide Instructions to Pilot Regarding Course, Upcoming Terrain, Hazards, Turning Points, Checkpoints	Map/Log, Aviator Knowledge	Many techniques are used, such as rally terms, clock headings. visual targets, etc. Some confusion not unusual.

FUNCTION: IIIA3 RADIO COMMUNICATION

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
TRANSMISSION:			
POSITION	Grid Coordinates, or Other Identifiers of Positions: Own Position Enemy Positions Other	Map/Aviator Knowledge	Coded or "thrust line" system for position transmission.
REQUESTS	Hazard Information Suppressive Fire Smoke Other	Map/Aviator Knowledge	Usually includes positional information.
RECEPTION:			
ADVISORIES	Artillery Hazards Instructions Other	Supported Unit	Positional information.
TARGET HAND-OFFS	Description Location Technique of Attack Method of Control Execution	Scouts	Pertains to attack aircraft.
BRIEFINGS	Threat Friendly Locations Possible AOP and Avoidance Areas	Supported Unit	

PHASE IV: ENGAGEMENT SEGMENT A: PRE-ATTACK

FUNCTION: IVA1 ARRIVE BATTLE POSITION, AOP, LZ

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
POSITION IDENTIFICATION	Verification by Time, Checkpoints, and Terrain Analysis that BP, AOP, or LZ is Correct	Map/Aviator Knowledge	
POSITION SITUATION	Determine Position Size, Winds, Hazards Entry and Exit Routes Hover Clearance	Aviator Observation	
COVER AND CONCEALMENT	Masking From Fire Masking From Observation	Aviator Observation	Select firing position if attack aircraft, AOP if observation mission.

FUNCTION: IVA2 PERFORM VISUAL OBSERVATION (RECON)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
SECTOR	Area of Visual Search	As Required	
INTELLIGENCE	That Applicable to Mission	As Appropriate	
ENEMY ACTIVITY	Enemy Movement, Position, Objects	Visual Detection	
ENEMY LOCATION	Grid Coordinates or Other Method	Map, Aviator Knowledge	Codes used in radio transmission of locations.

PHASE IV: ENGAGEMENT

SEGMENT B: TARGET ACQUISITION

FUNCTION: IVB1 RECEIVE TARGET DATA

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
TARGET TYPE	Tank, Other	Supported Unit	
TARGET DISTANCE	From Reference Point	Supported Unit	
TARGET DIRECTION	From Reference Point	Supported Unit	
TARGET LOCATION	Coordinates	Derived From Distance and Direction Information	Plot on map.

FUNCTION: IVB2 PERFORM VISUAL SEARCH

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
TARGET LOCATION	Visually Detect Target Identify Target Assure Correct Target by Identity and Location	Observation of Scanned Area Map/Aviator Knowledge	Compare target location with data received from supported unit. Plot new targets on map and report to supported unit.
TARGET VULNERABILITY	Target Cover Defensive Systems Range	Observation	

PHASE IV: ENGAGEMENT SEGMENT D: ENEMY DETECTION

FUNCTION: IVD1 MANEUVER TO NEW AOP/BATTLE POSITION

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
ENEMY DETECTION THREATENS AIRCRAFT	Muzzle Flash Movement Other	Observation	Evasive action and dash mode may be required.
NEW POSITION LOCATION	Preplanned Site	Map/Log	
	Newly Selected Site	Map/Observation	
PATH TO NEW POSITION	See Function IA5: Determine Route of Flight and Check-points	Map/Observation	Abbreviated route selection problem
FLIGHT TO NEW POSITION	See Function IIIA1: Determine Position	Map/Aviator Knowledge	
ARRIVAL AT NEW POSITION	See Function IVA1: Arrive Battle Posi-tion, AOP, LZ	Map/Aviator Observation	

PHASE V: RETURN TO STAGING AREA SEGMENT A: DEPART MANEUVER AREA

FUNCTION: VA1 DETERMINE RETURN ROUTE

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
PREPLANNED EXIT ROUTE AVAILABILITY	Ascertain Whether an Exit Route was Preplanned and Whether it is tactically advisable to use the Preplanned Route	Map/Aviator Knowledge	Must locate present position on map.
AVENUES OF APPROACH FOR EXIT ROUTE	See Function: IA6: Determine Route of Flight IA7: Determine Checkpoints IA8: Annotate Map IA9: Determine Altitudes IA10: Determine Airspeeds IA11: Time Estimates IA12: Fuel Requirements	Map/Aviator Knowledge	Used if exit route is not preplanned, or must be changed. These functions may be abbreviated if original exit route can be rejoined.

PHASE V: RETURN TO STAGING AREA

SEGMENT B: CRUISE NOE

FUNCTION: VB1 DETERMINE POSITION

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
See Function IIIA1			

FUNCTION: VB2 CREW COORDINATION (TOPOGRAPHIC)

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
See Function IIIA2			

FUNCTION: VB3 RADIO COMMUNICATION

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
See Function IIIA3			

PHASE VI: TERMINATION SEGMENT C: POSTFLIGHT

FUNCTION: VICI DEBRIEFING

INFORMATION REQUIREMENT	SPECIFICS	SOURCE	COMMENTS
ENEMY SITUATION: POSITION NUMBER ACTIVITY	As Required	Map/Aviator Knowledge	Explain information to Operations Officer and Intelligence Officer.
OTHER INTELLIGENCE	Terrain, Vegetation, Flight Hazards, Landing Zones, Current Weather, Other as Appropriate	Map/Aviator Knowledge	Accuracy to nearest six-digit coordinate

SECTION III

SPECIFIC TOPOGRAPHIC INFORMATION REQUIREMENTS

The analysis of information requirements presented in the preceeding section was reviewed to identify the task elements that can be accomplished only through the use of maps or map-like products. The result of this review was a listing of approximately 170 specific topographic information items typically required by the Army aviator. The majority of these information items are used for mission planning rather than in geographic orientation. Many of the information items do not pertain to visible features in the terrain, but are intelligence data that must be interpreted with reference to geographic positions or areas, such as suspected enemy positions or NBC-contaminated areas. These types of items are not depicted on standard military maps, but are added by pilots' annotations of the maps, by special overlays, or by notes kept in a flight log.

The listing of these items, labeled "*topographic information* specifics," is provided in the colored pages located at the end of this section. Adjacent to the information items is an array of columnar information. The first four columns summarize the methods used to depict the information items (point, linear, or area symbol), and indicate the probable necessity for additional alphanumeric information. The fifth column identifies the cases in which special computer processing of the information may be necessary or desirable. The nature of the special processing is noted in the last column. The sixth column flags the information items that involve contour interpretation--the most difficult of the decoding tasks required in map interpretation. Columns seven and eight indicate whether the information item is one that would be maintained in a permanent data base, or one that would be used only as a temporary entry in a rapidly changing tactical situation. Certain items fall in both categories; an example is a permanent terrain feature that may be temporarily identified as a checkpoint.

The comprehensive listing provided here is a distillation of the information items that must be made available to the Army aviator for the planning

and the conduct of flight operations. Consequently, the listing can be used during the iterative cycles of system design to insure that each of these information items is considered for depiction by the computer-generated topographic display.

TABLE III. SUMMARY OF TOPOGRAPHIC INFORMATION REQUIRED BY ARMY AVIATORS

FUNCTION NUMBER	*TOPOGRAPHIC INFORMATION SPECIFICS*	*POINT SYMBOL*	*LINEAR SYMBOL*	*AREA SYMBOL*	*ALPHANUMERICS*	*SPECIAL PROCESSING*	*CONTOUR INTERPRETATION*	*IN DATA BASE*	*TEMPORARY ENTRY*	*NOTES*
IA1 Receive Operations Order	Enemy Disposition	P		A					T	
	Enemy Strength				N				T	
	Friendly Disposition	P		A					T	
	Friendly Strength				N				T	
	Mission-Related Geographic Locations	P	L	A				D	T	
	Scheme of Maneuver		L	A			C	D	T	
	Fuel Locations	P							T	
	Armament Locations	P							T	
	Location of Division Command Post and Axis of Displacement	P	L						T	
IA2 Obtain Supplementary Information	Enemy AA Weapons, Sensor Capabilities, and Lock-on Ranges	P		A	N				T	
	Adjacent Units			A	N				T	
	Electronic Warfare			A					T	
	NBC Contamination			A					T	
	Radio Masking			A				D	T	
	Weather			A	N				T	
IA3 Acquire Maps, Photos, Overlays	Map Scale					S	C			Variable
	Map Contour Interval					S	C			Variable
	Map Type					S				Selectable
	Map Grid		L		N	S		D		
	Engineer Reports	P	L						T	
	"Shot-at" Reports	P							T	
	Boundaries		L					D	T	
	Hazards to Flight	P	L					D	T	
IA4 Perform Map and Aerial Photo Study	High and Low Ground					S	C	D		Display by shading, oblique, or perspective views
	Populated Areas			A	N			D		
	Battle Areas			A					T	
	Ambush Sites	P					C	D		
	Firing Positions	P				S	C	D	T	Compute fields of fire
	Landing Zones	P					C	D	T	
	Air Control Points	P			N		C	D	T	
	FEBA		L						T	

FUNCTION NUMBER	TOPOGRAPHIC INFORMATION SPECIFICS	POINT SYMBOL	LINEAR SYMBOL	AREA SYMBOL	ALPHANUMERICS	SPECIAL PROCESSING	CONTOUR INTERPRETATION	IN DATA BASE	TEMPORARY ENTRY	NOTES
IA4 (Continued)	Assembly Areas	P							T	
	Holding Areas	P							T	
	FARRP's	P							T	
	Key Terrain	P	L	A		S	C	D		Compute slope
	Open Areas			A			C	D		
	Vegetation Patterns			A				D		
	Ridgelines		L			S	C	D		Display by lines or profiles
	Drainage		L	A				D		
	Major Cultural Features	P	L	A	N			D		
	Known Enemy Positions	P		A					T	
	Suspected Enemy Positions	P		A					T	
IA5a, b, c	Target Locations	P							T	
Select Battle	Maximum Weapon Standoff Range			A						
Positions, Aerial	Maximum Observation Range			A				D	T	In data base; may
Observation Posi-	Cover and Concealment of Position			A		S	C	D	T	use graphics
tions, and LZ's	Cover and Concealment of Approach Routes			A		S	C	D	T	
IA6	Cover by Vegetation			A		S		D	T	Compute and display
Determine Primary	Cover by Terrain			A		S	C	D	T	Compute and display
and Alternate Routes	Concealment by Vegetation			A		S		D	T	Compute and display
of Flight	Concealment by Terrain			A		S	C	D	T	Compute and display
	Visual, Optical, and Electronic Surveillance			A		S	C	D	T	Compute and display
	Route Length		L		N	S				Compute and display
	Maneuver Space						C	D		
	Forced Landing Areas			A		S	C	D	T	Compute slope
	Friendly Artillery	P		A					T	
	Checkpoints	P			N		C	D	T	
	Air Control Points	P			N		C	D	T	
	Barrier Features	P	L				C	D	T	
	Sun, Moon Position				N	S				Compute and display

FUNCTION NUMBER	TOPOGRAPHIC INFORMATION SPECIFICS	POINT SYMBOL	LINEAR SYMBOL	AREA SYMBOL	ALPHANUMERICS	SPECIAL PROCESSING	CONTOUR INTERPRETATION	IN DATA BASE	TEMPORARY ENTRY	NOTES
IA7 Determine Air Control Points, Checkpoints, and Barriers	Availability	P	L	A			C	D		
	Perceptability					S	C	D		Determine features visible from a given point
	Discriminability						C	D		
	Reliability					S	C	D		Query system on data recency
	Linear Features		L				C	D		
	Funnels		L				C	D		
	Vertical Development	P	L		N	S	C	D		Query system for feature height
IA8 Annotate Map, Overlay, Flight Log	Course Lines		L						T	
	Air Control Points	P			N		C		T	
	Magnetic Headings				N	S			T	Headings automatically calculated
	Time or Mileage Tic Marks				N	S			T	Automated
	Mode of Flight Changes				N				T	
	Hazards to Flight	P			N				T	
	Boundaries		L					D	T	
	Flight Corridors			A					T	
	Barrier Features	P	L				C	D		
	Key Point Elevations				N	S	C	D		On demand
	Checkpoints	P			N		C	D	T	
	Enemy Forces	P		A					T	
	Friendly Forces	P		A					T	
	Radio Transmission Points	P		A				D	T	
	FEBA		L						T	
	FARRP's	P							T	
	Phase Lines		L						T	
	LZ's, Battle Positions	P							T	
	Holding Areas	P							T	
	Radio Nav Aids	P			N			D	T	
	Preplanned Artillery Targets	P							T	
	Rally/Pickup Points	P					C	D	T	
	Altitudes (Aircraft)				N				T	
	Airspeeds				N				T	
	Time Estimates				N				T	
	Weather			A	N				T	

FUNCTION NUMBER	TOPOGRAPHIC INFORMATION SPECIFICS	POINT SYMBOL	LINEAR SYMBOL	AREA SYMBOL	ALPHANUMERICS	SPECIAL PROCESSING	CONTOUR INTERPRETATION	IN DATA BASE	TEMPORARY ENTRY	NOTES
IA9 Determine Modes of Flight and Maximum Flight Altitudes	Enemy Proximity	P		A					T	
	Enemy Radar	P		A		S	C	D	T	Compute area coverage at given altitudes
	Enemy AA Weapons	P		A		S	C	D	T	Compute danger areas
	Route Elevations		L		N	S	C	D		Compute upper limits
	Route Contour		L		N	S	C	D		Compute slopes
	Route Vegetation			A				D		
	Obstacles	P	L	A				D	T	
IA10 Determine Average Airspeeds for Each Leg	Length of each leg of flight from staging area to objective and return		L		N	S			T	Function automated, given the information specifics
	Features affecting airspeed, such as slope, altitude						C	D		
	Gross Weight									
	Aircraft Performance									
	Flight Mode									
	Special Timing Requirements									
IA11 Calculate Time Extimates	Objective Arrival Time				N	S				All calculations automated given airspeeds, objective arrival time, and mission performance time
	Enroute and Arrival Times for Each Leg				N	S				
	Time From Staging Area to Objective				N	S				
	Time to Depart Staging Area				N	S				
	Time Required for Mission Performance				N	S				"
	Return Time				N	S				"
	Total Flight Time				N	S				"
IA12 Determine Fuel Requirements	Flight Distance				N	S				Function automated given proper specifics
	Flight Altitude									
	Flight Airspeeds									
	Total Flight Time									
	Wind									
	Density Altitude									

FUNCTION NUMBER	TOPOGRAPHIC INFORMATION SPECIFICS	POINT SYMBOL	LINEAR SYMBOL	AREA SYMBOL	ALPHANUMERICS	SPECIAL PROCESSING	CONTOUR INTERPRETATION	IN DATA BASE	TEMPORARY ENTRY	NOTES
IA13	Primary Target Locations	P							T	
Select Armament and Special Equipment	Secondary Target Locations	P							T	
IA14	Coordinates of Likely Enemy Positions	P			N				T	
Coordinate Fire Support	Preplanned Target Code Names	P			N				T	
	Artillery Air Corridor Locations, Times, Priorities		L	A	N	S			T	Warning alarm
IA15	Tactical Contingencies	P	L	A			C	D		
Conduct Contingency	Environmental Contingencies	P	L	A			C	D		
Planning	Escape and Evasion	P	L	A			C	D		
IA16										
Final Weather Check	Visibility		L		N				T	
	Density Altitude		L		N				T	
	Winds		L		N				T	
	Icing		L		N				T	
IB1	Enemy Situation	P		A					T	
Brief Crew	Friendly Situation	P		A					T	
	Weather			A					T	
	EW, NBC			A					T	
	Mission	P	L						T	
	Flight Routes		L				C	D	T	
	Airspeeds				N				T	
	Altitudes				N				T	
	Landforms			A		S	C	D		< Display oblique or perspective views
	Vegetation				N			D		
	Drainage		L					D		
	Hazards	P	L		N			D	T	
	Air Control Points	P			N		C	D	T	
	Checkpoints	P			N		C	D	T	
	Preplanned Targets	P			N				T	
	Contingencies	P	L	A						
	Fuel Locations	p							t	

FUNCTION NUMBER	*TOPOGRAPHIC INFORMATION SPECIFICS*	*POINT SYMBOL*	*LINEAR SYMBOL*	*AREA SYMBOL*	*ALPHANUMERICS*	*SPECIAL PROCESSING*	*CONTOUR INTERPRETATION*	*IN DATA BASE*	*TEMPORARY ENTRY*	*NOTES*
IB1 (Continued)	Armament Locations	P							T	
	Location of Division CP	P							T	
IB2	General Route		L				C		T	
Brief Passengers	Altitude				N				T	
	LZ	P							T	
IIIA1	Deduced Position (from speed, time, and heading)	P								
Determine Position	Checkpoint Identification	P					C	D	T	
	Contour Interpretation			A		S	C	D		Perspective or oblique views
	Symbol Interpretation	P	L	A	N	S		D		Alphanumerics
	Map-terrain Correlation					S	C	D		Terrain correlation technology
	Bearing to Features				N	S		D		Computed
	Barrier Feature Identification	P	L				C	D		
IIIA2	Navigator describes present position with reference to planned course	P	L	A		S	C	D	T	Terrain correlation technology
Crew Coordination	Navitator provides instructions to pilot regarding turns, hazards, checkpoints	P	L	A		S	C	D	T	Predictive display
IIIA3	Transmit Positions:									
Radio Communication	Own	P			N	S			T	Coordinates given
	Enemy	P			N	S			T	upon demand by
	Other	P			N	S			T	locating a cursor
	Receive Positions:									
	Targets	P				S			T	Numeric entry
	Artillery Hazards	P				S			T	used to locate
	Other	P				S			T	cursor

FUNCTION NUMBER	TOPOGRAPHIC INFORMATION SPECIFICS	POINT SYMBOL	LINEAR SYMBOL	AREA SYMBOL	ALPHANUMERICS	SPECIAL PROCESSING	CONTOUR INTERPRETATION	IN DATA BASE	TEMPORARY ENTRY	NOTES
IVA1 Arrive Battle Position, AOP, LZ	Verify correct by time, check-points, terrain analysis	P	L	A		S	C	D	T	Terrain Correlation
IVA2 Perform Visual Observation	Enemy Locations grid coordinates	P			N	S	C	D	T	Cursor - numeric interpreter
IVB1 Receive Target Data	Distance From Reference Point	P					C	D	T	
	Direction From Reference Point	P					C	D	T	
	Location (Derived)	P				S			T	Computed
IVB2 Perform Visual Search	Assure correct target by identity and location	P					C	D	T	
IVD1 Maneuver to New AOP/Battle Position	Preplanned Site Location	P							T	
	Selection of New Site	P					C	D	T	
	Determine Route of Flight to Site		L			S	C	D		Masking
	Determine Position During Flight	P	L			S	C	D		Terrain correlation
	Verify Arrival at New Site	P				S	C	D		Terrain correlation
VA1 Determine Return Route	Location of Present Position	P					C	D		
	Availability of Preplanned Return Route		L							
	Tactical Advisability of Pre-planned Return Route						C			
	Plan New Return Route--See Functions:									
	IA6--Determine Route of Flight	P	L	A		S	C	D		
	IA7--Determine Checkpoints	P	L	A		S	C	D		
	IA8--Annotate Map	P	L	A	N				T	
	IA9--Determine Modes of Flight and Altitudes	P	L	A	N	S	C		T	
	IA10--Determine Airspeeds		L		N	S			T	
	IA11--Time Estimates				N	S			T	
	IA12--Fuel Requirements				N	S			T	

FUNCTION NUMBER	TOPOGRAPHIC INFORMATION SPECIFICS	POINT SYMBOL	LINEAR SYMBOL	AREA SYMBOL	ALPHANUMERICS	SPECIAL PROCESSING	CONTOUR INTERPRETATION	IN DATA BASE	TEMPORARY ENTRY	NOTES
VB1	Same as Functions:									
Determine Position	IIIA1	P	L	A	N	S	C	D	T	
VB2	IIIA2	P	L	A		S	C	D	T	
Crew Coordination	IIIA3	P				S		D	T	
VB3										
Radio Communication										
VIC1	Enemy Positions	P		A	N		C	D	T	Record keeping
Debriefing	Other Locations, as Required	P	L	A	N		C	D	T	Record keeping

SECTION IV

KEY FEATURES FOR A COMPUTER-GENERATED TOPOGRAPHIC DISPLAY

The listing of map-related information items presented in the preceeding section of this report indicates the broad requirements that must be fulfilled by a topographic display system. The present section summarizes these requirements, and describes the computer-graphic techniques likely to be of greatest assistance in the performance of Army aviation tasks. The information presented in this section is not intended to comprise a comprehensive set of design recommendations, but describes a number of potentially valuable features identified during the review of recent developments in computer graphics. All of the computer-graphic techniques described are within the current state-of-the-art.

In considering the computer-graphic techniques applicable to providing the aviator with topographic information best meeting his momentary needs, four basic types of display functions emerged:

- Neo-Cartographic Functions
- Landform Visualization Methods
- Aircraft Masking Computations
- Navigation and Flight Management Aids

In the following pages each of these functions is described, and the component computer graphic techniques are presented. Each potentially valuable technique is discussed in terms of the nature of the task requirements, the information-processing burden on the aviator, special problems encountered in the high-threat environment, and the possible satisfaction of these demands by a computer-generated topographic display.

A. NEO-CARTOGRAPHIC FUNCTIONS

Because of the high cost of producing paper maps, virtually all products of the Defense Mapping Agency are designed to serve the needs of several different classes of users. It would be impossible to produce maps with all the information desired by all the potential users without cluttering the maps beyond the point of legibility. Consequently, some compromises must be made in each map's information content, so that each class of user is likely to find the map deficient in some manner. Even a map designed for a single class of user often could not present all of the useful topographic information because of the clutter problem, and the cartographer is forced to make judgments regarding the items of information best omitted. To maximize the available information, the aviator may attempt to obtain more than one map of the area of operations in order to study the topography as it is portrayed by different map scales, contour intervals, and feature selection processes.

In the tactical setting, the aviator always attempts to modify maps to suit his particular needs. Annotations and overlays are added to maps to present critical information such as the friendly and enemy situation, planned course lines, and so forth. This "customizing" of the topographic information presentation helps the aviator to perform his mission, but is often clumsy and time-consuming, and may introduce errors. Furthermore the "customized" products must be done in anticipation of in-flight requirements, and may be found wanting during actual conduct of the mission. A computer-based topographic display system would permit the aviator to design his own "ideal" maps for mission planning and in-flight use, varying the scale, contour interval, and feature selection rules as necessary. Such a system would also allow the aviator to select special overlays for temporary display and to remove them for clutter avoidance. In addition to these graphic presentation roles, the computer-based system could be programmed to provide alphanumeric information as required, amplifying the aviator's understanding of the graphic symbology.

SCALE SELECTABILITY

Discussion of Requirements. There is little question that accurate navigation at NOE altitudes requires a large-scale map; most members of the Army aviation community agree that map scales smaller than about 1:50,000 are inappropriate for NOE navigation. Even larger scale maps might sometimes be selected were it not for their rarity and limited area coverage. On the other hand, somewhat smaller scale maps are useful in portraying a wider area for mission planning purposes. Maps are seldom available in scales between 1:50,000 and 1:250,000. Thus the aviator usually must choose between a map which portrays approximately 240 square miles and one which portrays about 6,000 square miles (see Figure 3).

Computer-Generated Display Applications. A computer-generated topographic display can provide map scale selectability for the Army aviator. The data base may be employed to portray the terrain in any scale desired. A small scale would probably be employed to study the overall "lay of the land." Occasional changes to a larger scale would provide the more precise information needed for certain aspects of mission planning. During flight the scale could be varied to compliment the speed of the aircraft, the view of the surrounding terrain, the precision of information necessary for orientation, and the look-ahead distance desirable for the specific mission.

CONTOUR INTERVAL SELECTABILITY

Discussion of Requirements. The contour information on maps is required for scores of route selection and tactical decision-making tasks. Furthermore, it is usually the most valuable information on the map for navigation and geographic orientation. The precision of terrain-feature depiction required for NOE navigation is often misunderstood. Although NOE flight may take place in areas of large elevation ranges, the specific features used for geographic orientation in these areas are often quite small. These smaller features are of great importance as checkpoints because the large

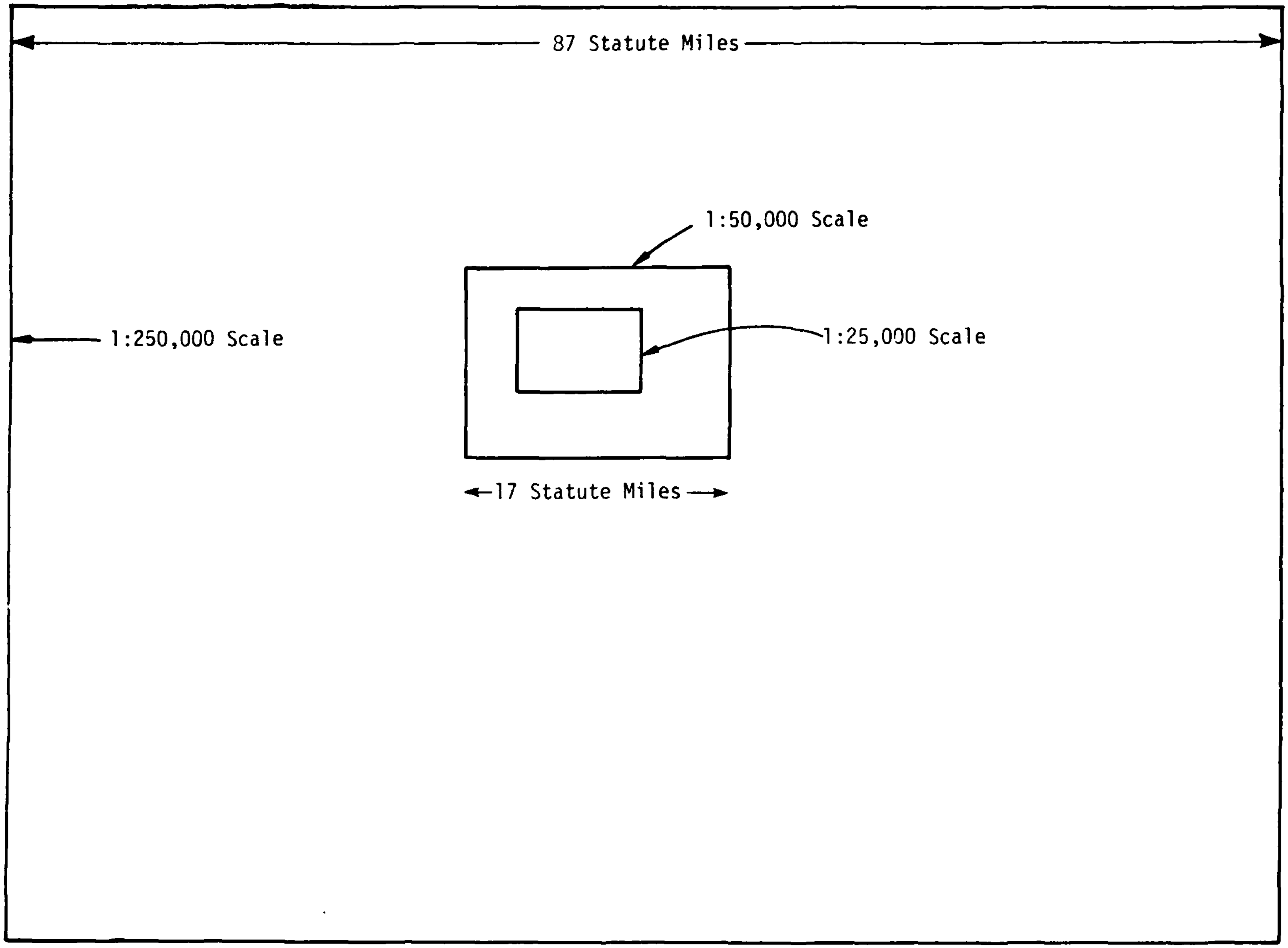


Figure 3. Comparative area coverage by maps in 1:250,000, 1:50,000, and 1:25,000 scale.

features may be obscured by the nearer, smaller features, and because the apparent forms of large features may be distorted or ambiguous due to the pilot's upward angle of view from his usually very low altitude. Thus, it is not unusual for Army aviators to navigate by referencing hillocks, saddles, stream beds, and other terrain features which may have a vertical development of only 50 feet or less, even though mountains may rise hundreds or thousands of feet near the flight path. In general, NOE aviators agree that a 40-foot contour interval is the maximum interval acceptable for portraying the types of landforms employed for NOE geographic orientation. Larger intervals introduce an unacceptable level of uncertainty regarding the actual shapes of the depicted landforms. The smaller the contour interval, the more detailed is the depiction of landforms, but the optimal contour interval depends also upon the steepness of the terrain. A very small contour interval helps to define the landforms in relatively flat terrain. The same contour interval cannot be used in steep terrain because the lines would abut and form dark areas devoid of contour information. The contour interval on paper maps is, of course, fixed. The cartographer must select a compromise contour interval for each map sheet, although supplementary contours may be added if the cartographer feels they would be useful.

Computer-Generated Display Applications. The computer-generated topographic display system can be designed to display the contour interval selected by the aviator, thus meeting the changing requirements for precision and improving the ease of interpretation. A large contour interval might be selected during the initial phases of mission planning, to provide a generalized view of the area's major landforms. Smaller contour intervals could be selected for studying potential flight routes, checkpoints, attack positions, and so forth (see Figure 4).

The useful range of adjustment may be increased by changing the scale of the display; a larger scale could be used with a smaller contour interval and conversely, a smaller scale could be used to view a wider area with a larger contour interval to prevent the contour lines from abutting. While there is little research bearing directly on the problem, it seems

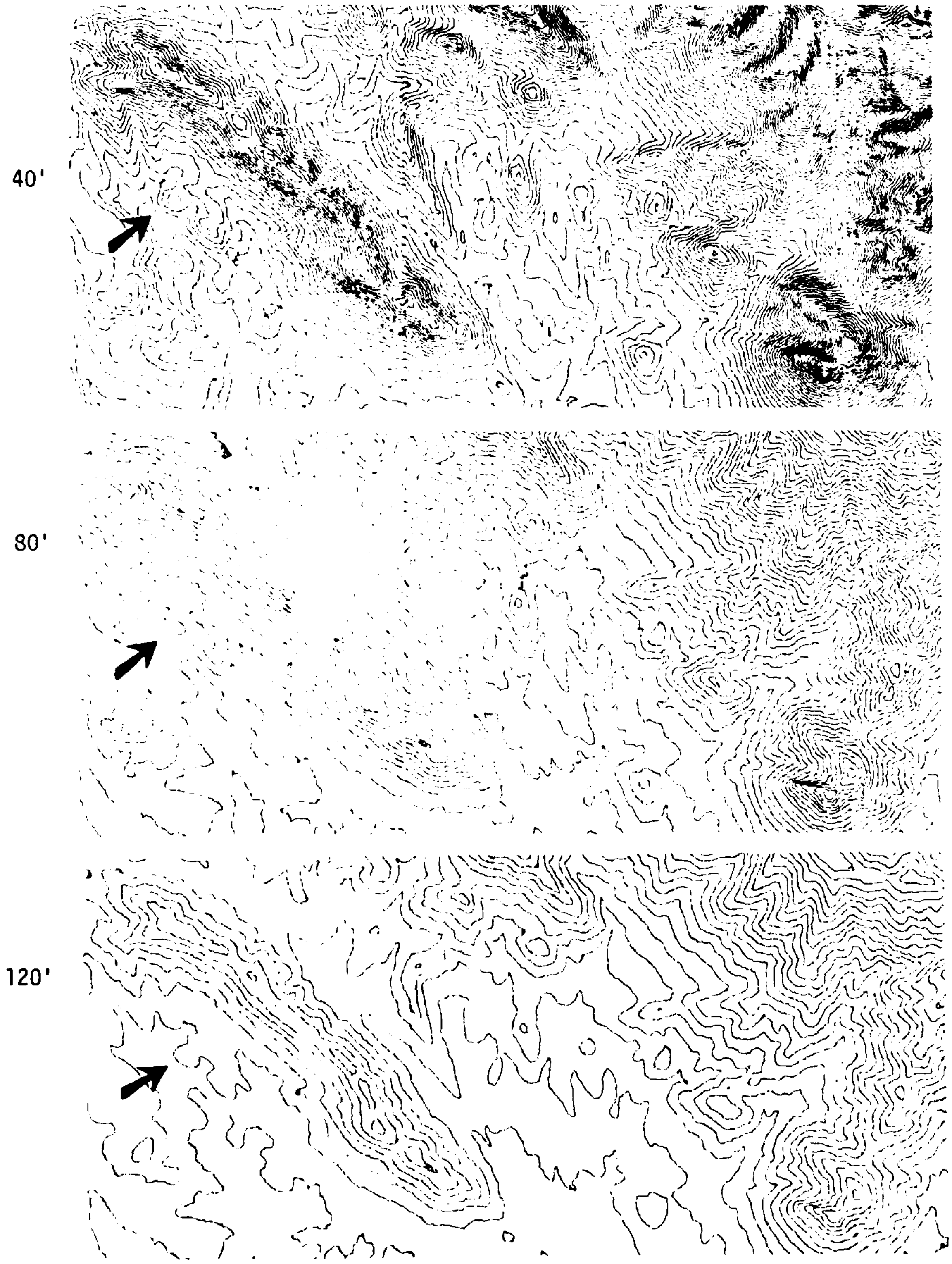


Figure 4. Depiction of terrain by computer-generated contour lines in intervals of 40, 80, and 120 feet. Note changes in definition of small hill indicated by arrow.

likely that adjusting the scale to that required by the task, then adjusting the contour interval to the minimum possible without line abutment will produce the most easily interpretable contour line display for visualizing landform shapes. For visualizing spatial relationships between major landforms, a much larger contour interval may be optimal.

HYDROGRAPHIC, VEGETATION, AND CULTURAL FEATURE SELECTABILITY

Discussion of Requirements. The portrayal of various hydrographic, vegetation, and cultural features may or may not be required. If they become key terrain in certain tactical situations, or are by their nature good navigational checkpoints, their portrayal becomes important. While nearly any feature could become key terrain in some circumstances, there are certain criteria for goodness of checkpoints. Regardless of the nature or nomenclature of checkpoints, there are four tests of checkpoint adequacy: *availability* (is it there?), *reliability* (has it changed?), *perceptibility* (can it be seen?), and *discriminability* (can it be positively identified?). It is not possible to rank hydrographic, vegetation, and cultural features in order of their value as navigational checkpoints without very carefully defining the circumstances. Categories of features valuable in some situations are of little help in others. Hydrographic features are important for tactical decision-making and are usually available and often reliable checkpoints. Depending upon a number of factors such as their size, number, and surrounding vegetation, they may or may not be perceptible or discriminable. Vegetation features are usually available and perceptible, but may not be reliable or discriminable, depending upon the geographic area. If cultural features are available, they are often easily perceptible, and usually are more discriminable than the most subtle variations in their natural surroundings. Their reliability ranges from very good to very poor, and is degraded in proportion to the passage of time since compilation of the map data.

The cartographer, in compiling information for a paper map, must decide what features are to be portrayed. His decisions are based on the necessity

of making the map useful to the broadest possible range of users, and the objective of avoiding clutter. As a result of these decisions, the features portrayed on the map may or may not be adequate checkpoints for the Army aviator during NOE flight.

Computer-Generated Display Applications. A computer-generated topographic display could permit the aviator to tailor the feature selection rules to best suit his needs depending upon the type of terrain and the level of clutter acceptable on the display screen. This tailoring might take the form of selecting or eliminating an entire class of features. For example, all cultural features might be displayed in an area where their reliability is good, and no vegetation codes would be depicted where the vegetation patterns in the terrain are indiscriminable (see Figure 5). More complex feature selection rules could be involved. The aviator could be given control over the criteria governing the selection of specific features within a given class to be displayed, such as displaying only the perennial drainage features and eliminating the intermittent streams. Like scale and contour interval selectability, feature selectability would permit the aviator to maximize the accuracy and utility of the topographic portrayal while minimizing the presence of irrelevant information and clutter on the display.

AUXILIARY DESCRIPTORS

Discussion of Requirements. A considerable amount of map-related information is expressed best by words and numbers, rather than by pictorial symbology. Foremost among these kinds of information items are place names--towns, roads, streams, hills, and scores of other features are labeled on standard topographic maps. Quite often these names are of little or no value to the Army aviator. In fact, in a series of studies on low level flight in Naval aircraft,[1] performance was actually improved when place names were removed from the map. Other descriptors on maps, such as grid

[1]McGrath and Osterhoff, 1969.

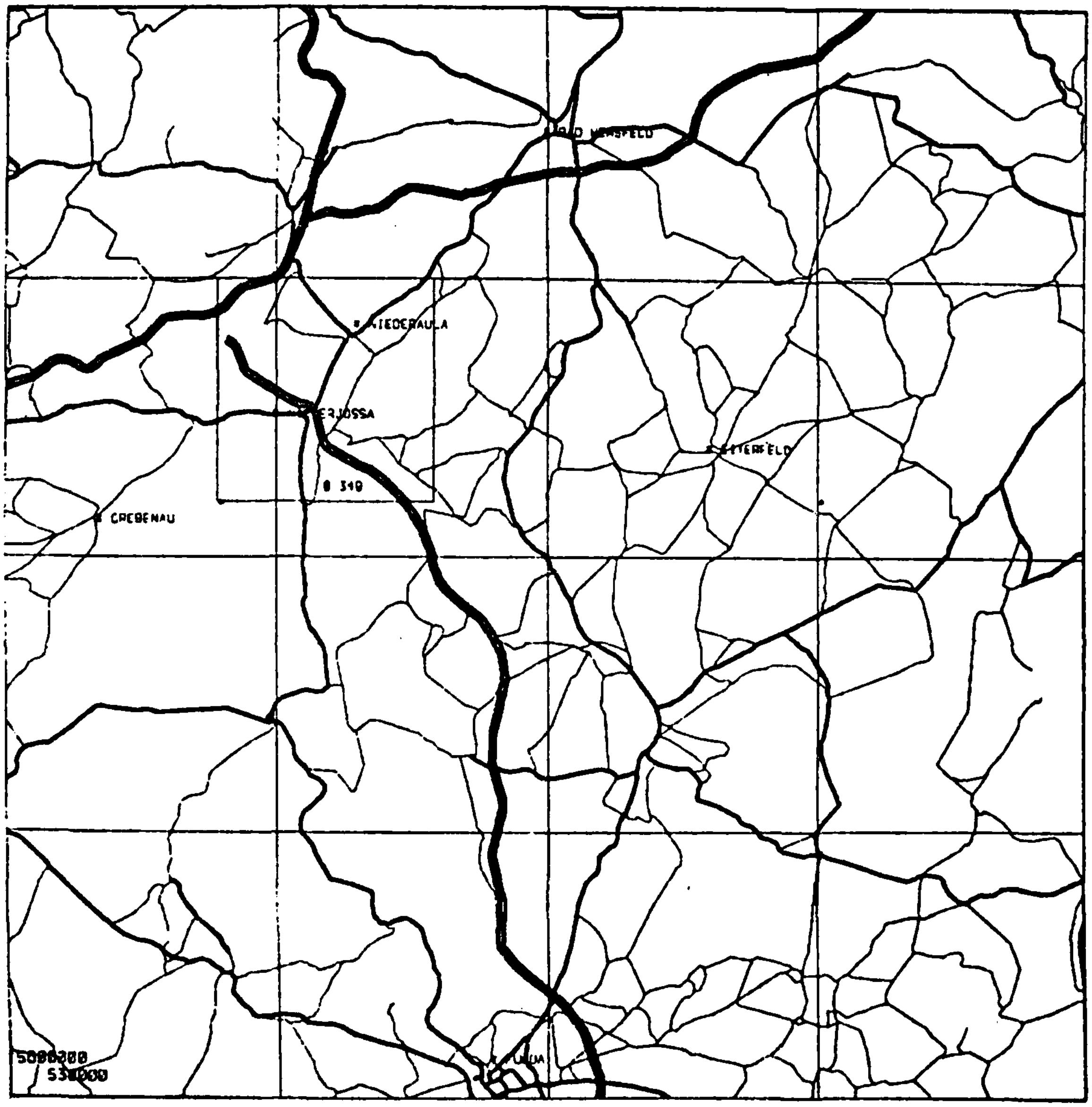


Figure 5. Sample of a computer-generated map of an area in Germany. Town names, and roads of three sizes have been selected for display. Vegetation and hydrographic features are omitted. (Figure courtesy of CACDA.)

line numbers, spot elevations, and marginal information may be of great importance to the aviator under certain conditions, and only unnecessary clutter the rest of the time.

Computer-Generated Display Applications. A computer-generated topographic display can provide the aviator with the auxiliary descriptive information he needs when it is desirable and otherwise omit all but the critical alphanumerics. A light pen might be used to indicate a symbol or position on the display in order to query the system regarding the feature name, grid coordinates, and elevation. Not only can such a system greatly simplify the extraction of information from the display as compared to paper map use, it can also be programmed, if desired, to display other known characteristics of the indicated feature. Various types of information could be retrieved for point, linear, or area symbols. Examples include the heights of cultural features, the materials used in road construction and the trafficability of open areas, if such information were available. These sorts of data may be presented in a peripheral position so that the topographic display area is never cluttered by alphanumerics, even though more information is potentially available than could possibly be presented on a standard topographic map.

ANNOTATION

Discussion of Requirements. In order to correlate mission information with the topography in the area of operations, the Army aviator must heavily annotate his map, either directly, or with a series of notes and overlays. Dozens of information items are absolutely required, and many more are extremely useful. It is noteworthy that the inability to make these annotations has been a critical shortcoming in the "projected" map display systems. Even with paper maps, aviators have found that direct annotations must be limited in number if the topographic information is not to be obscured, and that a limited amount of annotations are possible with overlays. Many annotations on a single overlay introduces unacceptable clutter, and attempting to use multiple overlays

introduces the problems of positioning errors and lost time in their selection and alignment.

Computer-Generated Display Applications. A computer-generated topographic display may be designed so that overlay information can be entered before the flight and instantly displayed during mission conduct. Some of the overlay information would probably be desired continuously, such as planned course lines and magnetic headings, while other data, such as weather, time estimates, and so forth, would only be displayed on command. Even if a substantial amount of annotation was required, the aviator would be able to momentarily delete this data in order to study the topographic data underlying the annotations, or to reverse the priority relationship so that the annotations would underly the topographic data.

Much of the annotation and overlay information employed by the aviator is battlefield situation data received from preflight briefings by the G2/S2 and G3/S3. Presently the aviator must either copy the situation onto his own map or map overlay, or receive an overlay with the operations order. A much more comprehensive situation display could be presented by issuing the aviator a cassette with the latest intelligence digitized for presentation on the computer-generated topographic display. The flexibility of the computer-generated annotation capability is certain to be of significant assistance to aviators, provided that the information entry and retrieval processes are natural and convenient ones.

POSITION DESIGNATION

Discussion of Requirements. Communications regarding point designations are recurring requirements for Army aviators. The six-digit grid coordinate is typically used to designate points on the map. Often it is a tactical requirement that the 100,000-meter square identification be included in any point designation. Additional digits may be used to locate a point within 10 meters. The use of the grid system to this level of accuracy requires that a coordinate scale be overlayed on the map in order to determine the

coordinates. The recipient of the orally communicated coordinates writes them down and uses a coordinate scale to plot the designated point on the map. While the grid system provides for extreme accuracy, it is commonly acknowledged that errors are not unusual in determining the coordinates of a point, communicating these coordinates, and using them to locate a point on the map.

Computer-Generated Display Applications. The computer-generated topographic display may be used to speed the point designation process while improving precision and decreasing errors. A light pen or other input device can be employed to position a cursor on the display. The coordinates of the cursor position would be numerically displayed to any desired level of accuracy. The recipient of the coordinates need only enter them via a keyboard and a symbol would appear at the appropriate position on the map display. The same position-marking features might be used to keep records during the flight that would be useful to the operations officer and intelligence officer. Thus the post-flight debriefings could be conducted more rapidly and the information conveyed more accurately than without this capability.

The system could also be programmed to provide range and bearing information between any two designated positions. The range and bearing feature would aid not only in intersection and resection problems, but also in target handoffs between observation and attack aircraft.

B. LANDFORM VISUALIZATION

The most difficult aspect of map interpretation is the visualization of landforms. Yet the ability to perform this complex perceptual task is an absolute requirement for route selection, geographic orientation, and a host of tactical decision-making activities.

A variety of schemes have been developed to encode terrain-relief information on maps. Elevation tints and gray tones, shaded relief, and hachures have been used to attempt to simplify the task of visualizing landforms.[2] But the simplification has always been accompanied by a decrement in precision of the terrain-relief information.

Only one terrain relief encodement technique has ever been able to meet the requirement for depicting landforms thousands of feet tall while maintaining sufficient precision for NOE navigation--contour lines. There is virtually no limit to the elevation range which may be depicted by contour lines, yet the precision of the information presented is limited only by the contour interval. It is unfortunate, however, that the interpretation of contour lines, that is, the *extraction* of the voluminous information contained in contour lines is so difficult.

The information processing requirement for contour interpretation for the purposes of geographic orientation may be thought of as occurring in three stages. In Stage I, the aviator studies the lines and mentally *"constructs"* the three-dimensional landform as seen from above. In Stage II, the constructed image is *"rotated"* to assume the aspect such an object would present when viewed from the NOE altitude and position. In Stage III, the aviator attempts to *correlate* the image with the landforms seen in the "real world" in order to pinpoint his position. The relative difficulty of these three stages is not well understood, but it may be said with some assurance that all are demanding, and together require an inordinant amount of cockpit

---

[2]For a full discussion of these schemes, see Cross, 1977.

time.[3] Furthermore, errors made in the first or second stages will be carried through the subsequent stages, making the geographic orientation task more difficult to perform, and degrading the precision with which the aircraft's position can be determined.

Landform visualization is required in mission planning activities as well as geographic orientation tasks. Many of the tactical decisions involved in route selection depend substantially, if not entirely, on an understanding of the lay-of-the-land. When aerial photographs are available for the mission area, aviators will study the photographs during mission planning. Both vertical and oblique views are useful, but oblique views are particularly helpful in understanding the configuration of the landforms. Unfortunately, oblique photographs may seldom be available for use by Army aviators.

Computer-based topographic display systems can employ special programs to assist the aviator in landform visualization, not only by improving the contour-line presentation, but also through the use of "drawings" of terrain as it must appear based upon the stored digital elevation data. Such drawings are analogous to the outcomes of Stage I and Stage II information processing activities--except that a computer system can generate these visualizations rapidly and accurately while an aviator cannot.

ELEVATION GRAY SHADES

Discussion of Requirements. Elevation gray shades (or tints) are unique shades of gray (or color) which can be used to define the layers between selected elevation contours. A four-shade "elevation guide" is often provided in the marginal information of a standard topographic map to provide the user with an overview of high and low terrain in the mapped area, as opposed to a precise navigational earth reference. Small-scale maps often include shades on the map itself to help in depicting major changes in landmass elevation.

[3]A recent study (Sanders, et al, 1979) showed that 92.2% of the co-pilot's visual time was occupied with the navigation task.

A recent experiment[4] employed maps constructed only of contour lines in a navigation and orientation test. A number of errors were made by participants in this experiment as a result of terrain "reversal," or mistaking ridgelines for valley floors. Clearly, elevation gray shades would have prevented this type of error.

The disadvantage of the elevation shade method is that a limited number of shades can be used on a map. Thus, the elevation interval represented by a shade would typically be rather large (often several hundred feet). Consequently, the precision of such a display is limited and while it might aid in portraying a large mountain in an area, it would probably not aid in discriminating one large mountain from others present in the vicinity.

Computer-Generated Display Applications. The computer-generated topographic display is capable of displaying both contour lines and elevation shades simultaneously (see Figure 6). Consequently, the display can offer the precision of the contour-line encodement as well as a rapid general shape visualization aid. While a limited number of shades is probably sufficient, the actual number could be left to the discretion of the aviator who might vary them in accord with the terrain elevation range and the ambient illumination (which affects the number of perceptible gray shades on such a display). In addition, the aviator may be given the option to adjust the elevation interval between shades, and to vary the elevation of the center-point of the shade spectrum in order to optimize the utility of this feature in simplifying landform visualization.

SHADED RELIEF

Discussion of Requirements. Relief shading has been used on topographic maps to indicate terrain elevation and slope by a shadow effect achieved by darkening one side of hills, ranges, or mountains. The degree of slope is

---

[4] Rogers and Cross, 1978.

Figure 6. Computer-generated gray shades aiding contour line interpretation.
(Figure courtesy Avionics R&D Activity)

indicated by the density of shading. On most such maps, the shaded relief is manually rendered with an airbrush and reflects the cartographer's interpretation of the relief.

The assumed light source in shaded relief maps is always from an oblique northwest direction which, in the northern hemisphere, does not correspond with the sun angle. This lack of correspondence may cause confusion if the aviator expects the shadows in the real world to be similar to those shown on the map. On the other hand, reversal-of-depth illusions have been produced by shaded surfaces illuminated from "below" or south. Further research will be required to clarify the circumstances in which confusion may result.

Computer-Generated Display Applications. A computer-generated topographic display has the potential of producing the useful aspects of shaded relief without incorporating human interpretation errors and an inappropriate light source. The sun (or moon) position at the time of the flight may be accounted for, as well as the reflectances and slopes of the feature surfaces in order to generate a scene of reasonable fidelity, limited only by the scale of the display and the density of elevation points in the data bank (see Figure 7). Such a display would offer the advantages of a large-scale relief map, but in an infinitely more flexible format. The shaded relief could be used alone or in conjunction with contour lines and with cultural, vegetation, and hydrographic features, as required by the aviator. The computer's capability to construct a representation of a three-dimensional landform from elevation data may prove to be a tremendous unburdening of the information processing tasks required of the Army aviator.

OBLIQUE VIEWS

Discussion of Requirements. An oblique view of the terrain is one which portrays the terrain as it might be seen from some angle between ground level and directly overhead. In Army aerial photographs, oblique views are typically obtained with camera inclined about 30 degrees (low oblique) or 60 degrees

Figure 7. Computer-generated shaded-relief view of Las Vegas, Nevada. (Figure courtesy of DMAAC)

(high oblique) from the vertical. The virtue of oblique views is that they present terrain from a more familiar point of regard than that provided by the vertical view, and features are usually more recognizable. In particular, terrain relief becomes much more discernible in an oblique view than in a vertical view.

The preflight uses of the oblique view included its employment in route selection, tactical decision-making, and route rehearsal. The oblique view simplifies the specification of good checkpoints, barrier features, battle positions, landing zones and many other such terrain-related mission-planning requirements. Examining the features as portrayed by the oblique view offers the aviator an opportunity to develop an "area familiarity" without exposing him to the unacceptable risk of flight hundreds of feet above the actual terrain in a high-threat environment. The oblique view offers a

stage for rehearsal of the flight and for envisioning the setting for offensive operations. An important disadvantage of oblique photographs is that they cannot be used to determine distances between features. Since photographs present a perspective ("vanishing point") view of terrain, their scale is not constant. Because of the risk and the time requirements involved in obtaining a sufficient number of oblique photographs to adequately cover an area of operations, they are unlikely to be available to Army aviators.

Computer-Generated Display Applications. A computer-generated topographic display system can, in many respects, substitute for oblique view photography. In other respects, computer-generated visualizations are superior to photographic imagery. The computer-generated topographic display can be used to generate oblique views by two methods: line drawings and shaded surfaces (see Figure 8). Computer-generated line drawings have been produced in several formats. One depicts the terrain by a series of curved, non-connecting lines. Another employs a grid network of lines which has the appearance of a "fishnet" draped over the landforms. Another format is provided by the use of the contour lines themselves, presented from an oblique view. All of these formats imply hidden lines or "occultation" so that the portrayed landforms are not transparent; their reverse sides and features behind them are not visible.

Shaded surfaces may be used for oblique views, just as they are employed for vertical views. The same considerations are involved in their computation--only the direction and angle of view are changed. Shaded surfaces appear more realistic than line drawings, but they are not, in fact, more accurate even though they give the impression of greater precision. A good deal of research remains to be done before either the shaded surface or the line drawing approach can be said to be superior in any given set of conditions.

Whether shaded surfaces or line drawings are constructed by the computer system, a photograph-like view of the terrain may be produced. That is, the display may be employed to construct a perspective view of the landform, as they might appear to the human eye, either at ground level, or at any chosen elevation above the terrain (see Figure 9). Another kind of oblique view

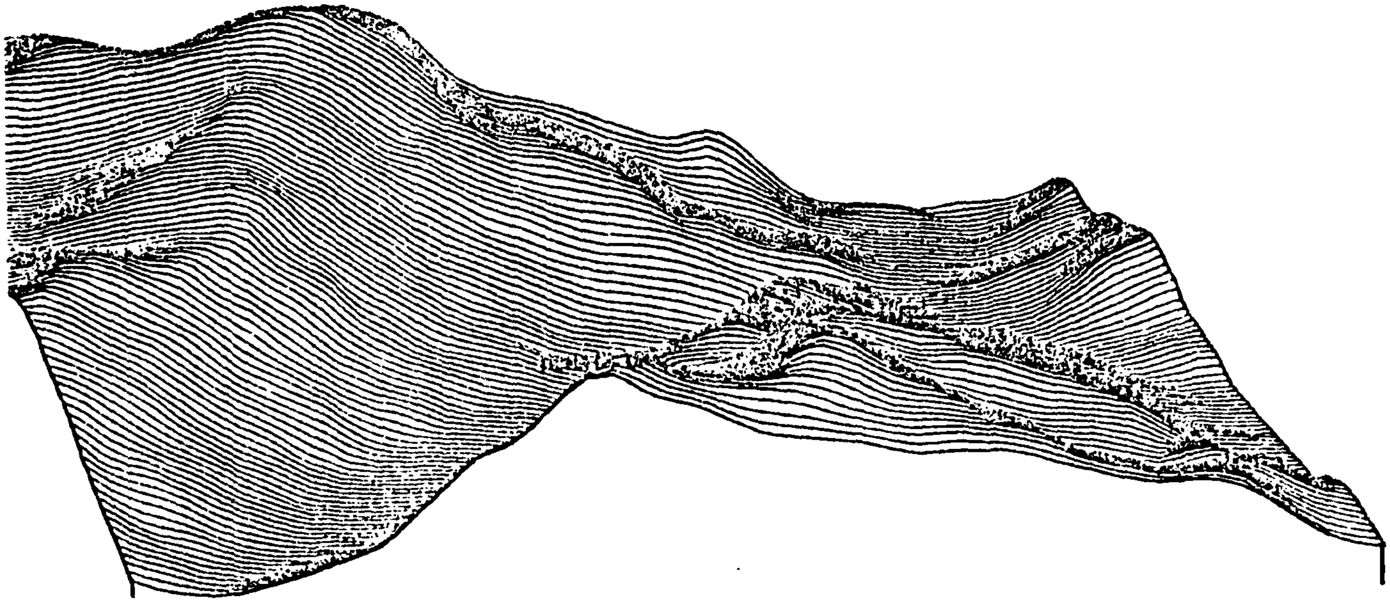


Figure 8. Samples of computer-generated oblique views: line drawing (courtesy of USMA) and shaded surface (courtesy of General Electric).

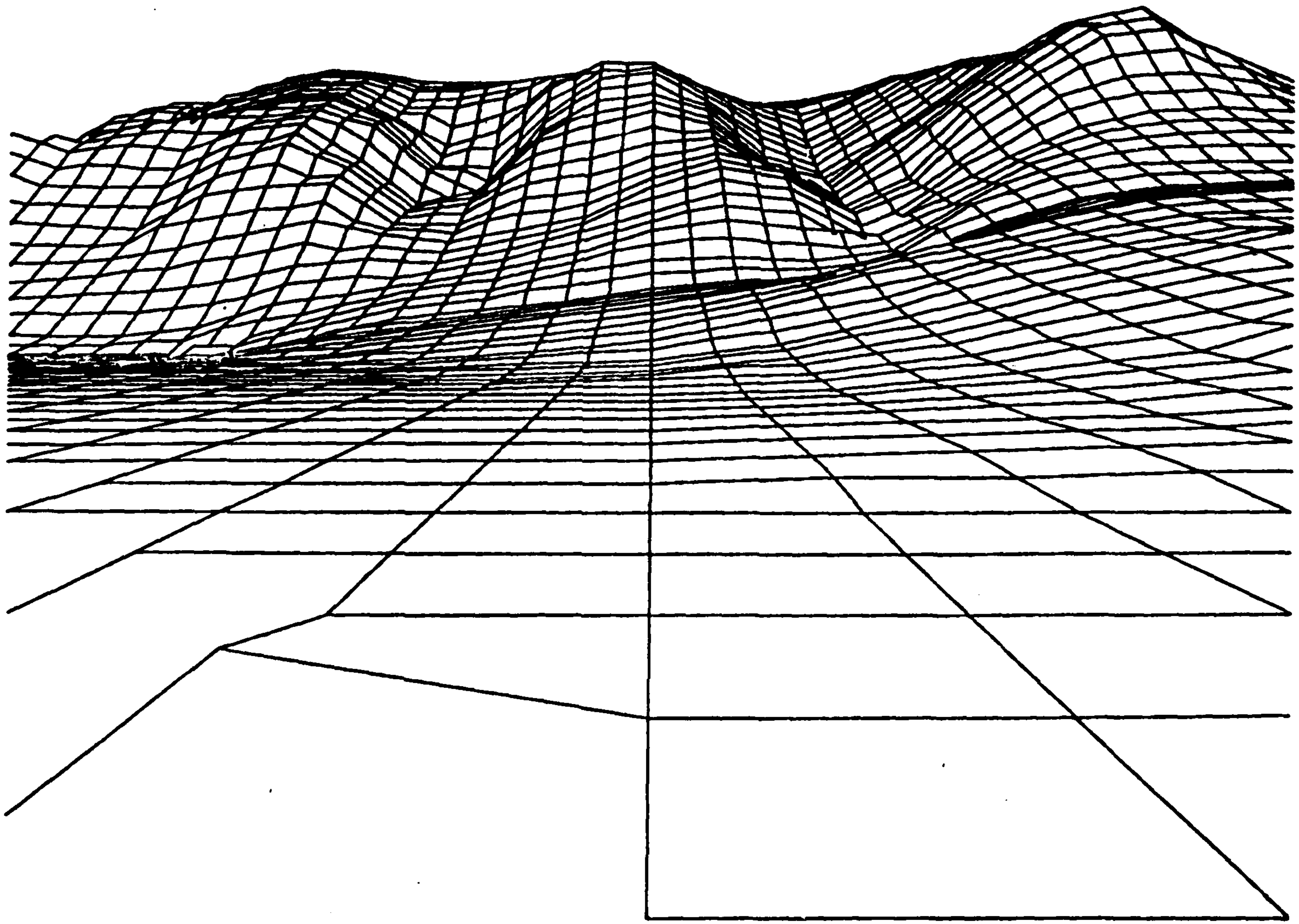


Figure 9. Computer-generated perspective view, employing the "fishnet" gridwork of lines. (Figure courtesy of CACDA.)

can be constructed by a computer-generated topographic display: the isometric projection. This kind of oblique view is unlike a photograph because it does not employ vanishing point perspective. Instead, ground distances are kept proportional and constant, as in an engineering drawing used for shop measurements. In this manner, three-dimensional landforms may be portrayed, yet distances may be measured between points--a significant advantage in flight planning (see Figure 10).

Either type of oblique view may be enhanced by some degree of vertical exaggeration. Researchers exploring computer-generated oblique views have usually exaggerated the vertical scale of their products, just as relief map makers have done for many years. There is some consensus among observers that the exaggeration makes the scene appear more realistic. The exaggeration is increased as the map scale decreases; large scale oblique views typically employ a 3x vertical exaggeration, while small scale views may employ a 30x exaggeration. No research has yet been conducted to determine the optimal vertical exaggeration (if any) in oblique views. Perhaps like map scale and contour interval, exaggeration should be left to the discretion of the aviator.

The uses of oblique views are numerous but may be divided into three classes: training, preflight, and in-flight. The utility of a computer-generated display system for training individuals in landform visualization seems indisputable. Computer-constructed oblique views would offer much more effective illustrations of contour-line interpretation than can artists' renditions. The terrain feature depiction could be rotated in any axis to enable the student to appreciate the changing apparent form of the features, depending upon angle of regard. The flexibility of the depiction would help the student learn to focus his attention upon portions of the features that might permit him to identify them with some certainty regardless of his vantage point.

The preflight uses of the oblique view are similar to those of aerial photographs. The oblique view provides visualizations valuable in route selection and tactical decision-making. In addition, the Army aviator can use computer-generated oblique views to mentally rehearse the conduct of

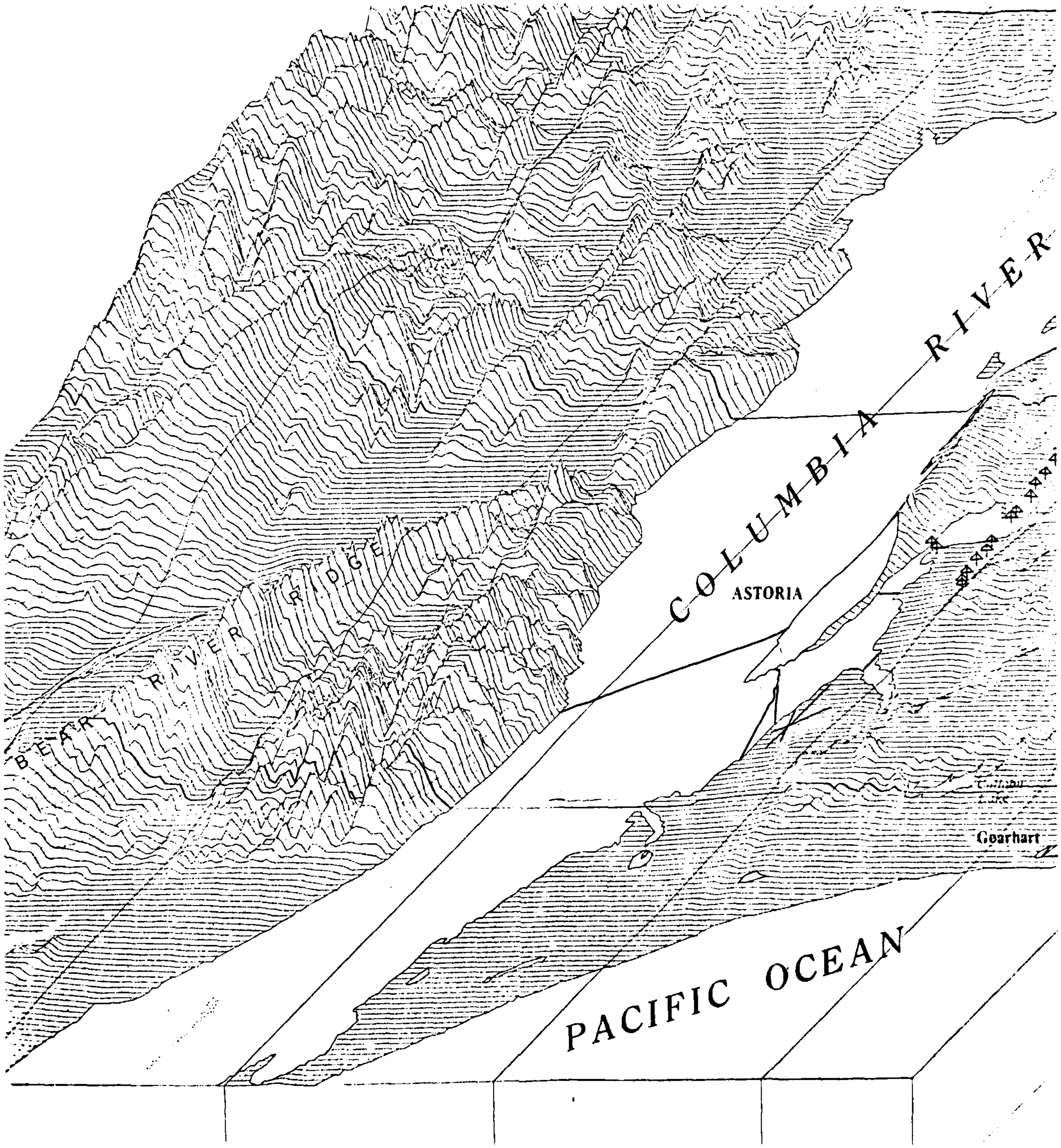


Figure 10. Computer-generated oblique view, using an isometric projection rather than a perspective view. (Figure courtesy of DMAAC.)

his mission. The aviator need not search out or request specific aerial photographs, but can select exactly the views he needs to examine the terrain--either from well above ground level, or from NOE altitude. Furthermore, the views can be projections usable for distance measurement, or perspective views to study landforms as they will appear during the flight. Cultural, hydrographic, and vegetation features may be added to the contour visualizations, as desired (see Figure 11).

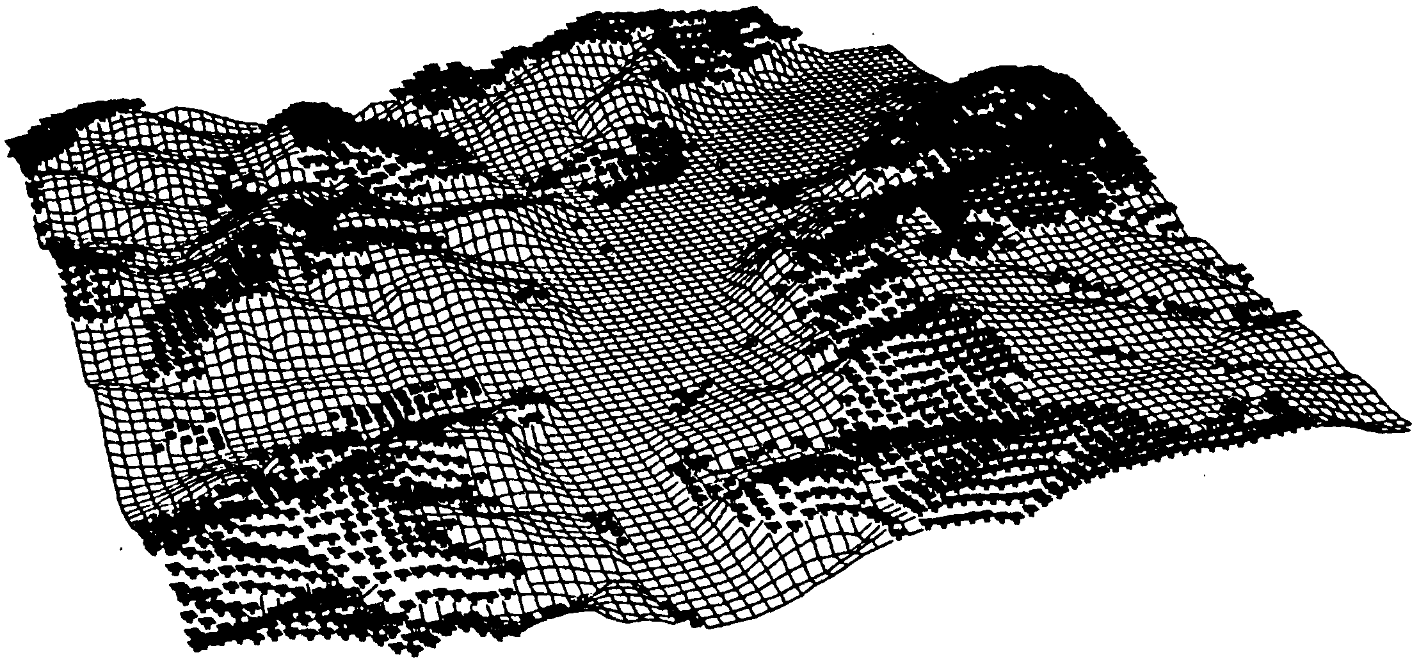


Figure 11. Computer-generated oblique view incorporating vegetation patterns. (Figure courtesy of CACDA)

The potential inflight uses of the oblique view are incompletely understood. A high oblique view in isometric projection might possibly provide a navigation display in some respects superior to a plan view. The perspective view, on the other hand, has little to recommend it as a navigation display. Specifically, if a perspective view was not in agreement with the landforms seen in the terrain, the aviator would realize that his aircraft was not on

the planned course, but such a navigation display would offer no information regarding the action necessary to recover the proper flight path.

It is possible that the ability to change the display between a vertical and an oblique view while in flight might provide the aviator with an appreciation of the terrain that neither view alone would be capable of imparting. However, presently available information indicates that the greatest potential of the oblique view will be in its tremendous assistance in landform visualization for mission-planning activities.

C. AIRCRAFT MASKING COMPUTATIONS

The term "masking" refers collectively to cover from weapons fire and concealment from visual, optical, or electronic observation. Masking is the central objective of terrain flight, whether of the nap-of-the-earth (NOE, contour, or low-level type. NOE flight is defined as flight as close to the earth's surface as vegetation and obstacles will permit, varying airspeed, altitude, and heading as required. Contour flight is flight generally conforming to the contours of the earth, varying airspeed and altitude, but following a more direct route than used in NOE flight. Low-level flight is flight conforming generally to a straight line, with constant airspeed and altitude.

It is critical that the aviator be aware of the positions and altitudes at which masking is or is not available. Flying unmasked sharply reduces survival probability in the high-threat environment. On the other hand, unnecessary NOE flight is inefficient because more sorties can be flown or greater distances covered using contour or low-level flight. Furthermore, higher altitudes offer a greater margin of safety in dealing with aircraft emergencies and hazard avoidance.

Although the importance of masking is clear, no practical methods of accurately determining the masked areas and altitudes from map study have been devised, except for the most obvious situations and solutions. For example, FM 1-1, Terrain Flying, offers only this advice on planning masked routes:

> "To do this in mountainous or rolling terrain, plan the route on the friendly side and below the crest of a ridge-line. In very gently rolling terrain, plan the route across the low terrain such as stream beds where it does not serve as an avenue of approach to the enemy position. In arid or open areas, plan the route along stream beds or depressions where trees may exist."

Examination of standard topographic maps indicates that the masking determinations will often be considerably more complex. The procedure for

manually plotting masked areas, based on a series of profiles, is described in FM 21-26, Map Reading. This procedure entails an extremely time-consuming series of steps to plot the masked areas for even a relatively small geographical expanse. Such an approach is totally impractical for an aviator who needs to determine the masking available in broad and long flight corridors, with several known or suspected enemy positions in the area of operations.

A computer-generated topographic display may perhaps make its greatest contribution in the computation of masked areas and altitudes for terrain flight. Such computations are relatively simple ones, but the requirement for hundreds or thousands of computations is the arena in which computers are most valuable and efficient.

MASKING PLOTS

Discussion of Requirements. In order to provide an appreciation of the difficulty of producing a masking plot without computer assistance this subsection will describe the procedure as presented in FM 21-26. The procedure entails the construction of profiles, use of the profiles in drawing defilade diagrams, and use of the defilade diagrams in plotting masked areas.

The construction of a profile requires the following steps (see Figure 12):

(1) Draw a line (profile line) on the map along the line for which a profile is desired.

(2) Find the value of the highest and lowest contour lines that cross or touch the profile line. Add one contour value above the highest and one below the lowest to take care of hills and valleys.

(3) On a blank sheet of paper draw equally spaced horizontal lines. Draw enough lines so that there will be one line representing each contour value as determined in (2) above.

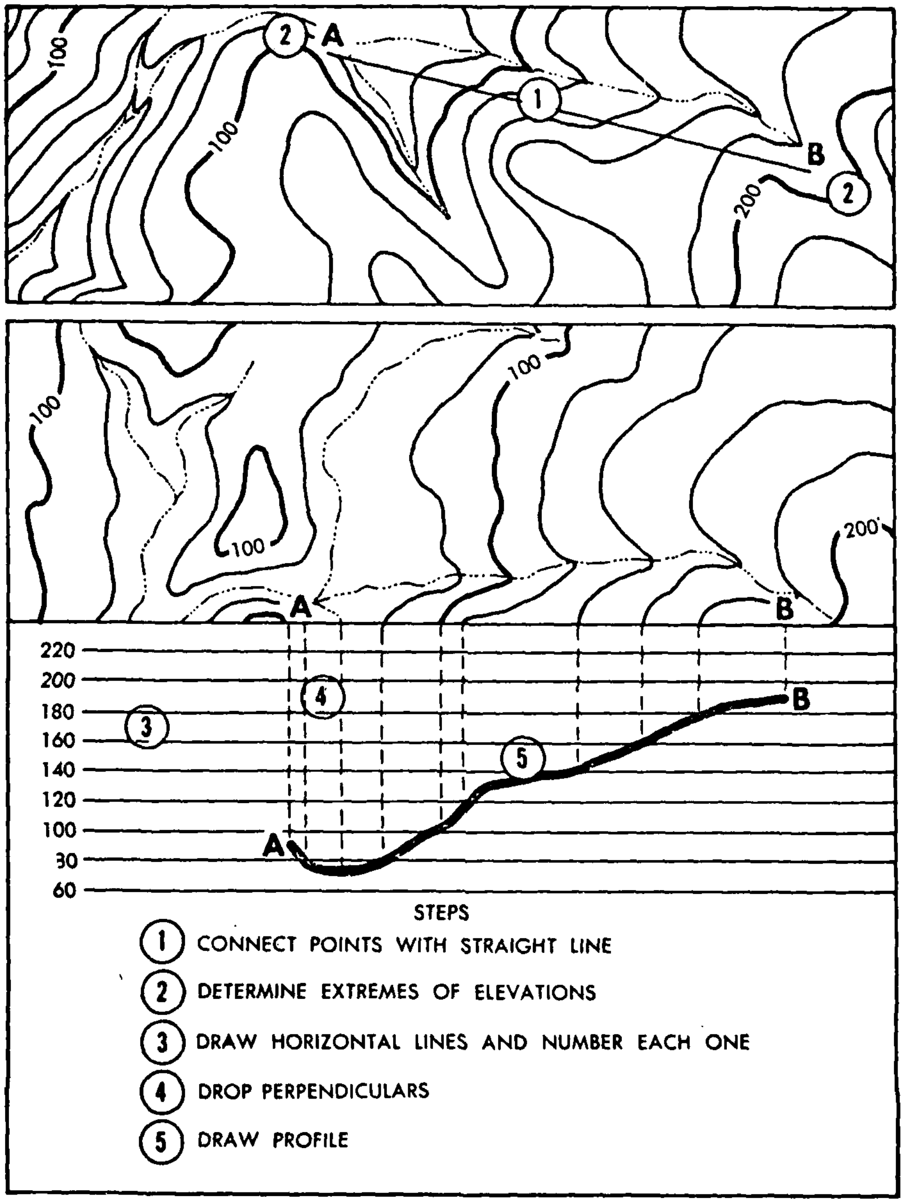


Figure 12. Drawing a profile.

(4) Place the lined paper on the map with the lines adjacent and parallel to the profile line.

(5) Number the line on the lined paper, closest to the profile line with the highest value determined in (2) above.

(6) Number the rest of the lines in sequence down to the lowest value on the line farthest from the profile line.

(7) From every point on the profile line where a contour line crosses or touches, drop a perpendicular to the line having the same value as the contour line. Place a tick mark where the perpendicular line cross the line.

(8) The highest point of hills and the lowest point of valleys will have to be determined by interpolation and then a perpendicular dropped to their interpolated value.

(9) After all perpendiculars have been dropped to the lined paper, connect all tick marks with a smooth, natural curve. Remember that hills and valleys are usually rounded. Streams, however, tend to form a sharp V-sharp or a U-shape.

(10) The profile just drawn may be exaggerated. The spacing between the lines drawn in (3) above will determine the amount of exaggeration and may be varied to suit any purpose.

Once the profile has been completed, a straight-edge may be used to draw lines of sight from any given point on the profile. The resulting illustration is a defilade diagram, as shown in Figure 13.

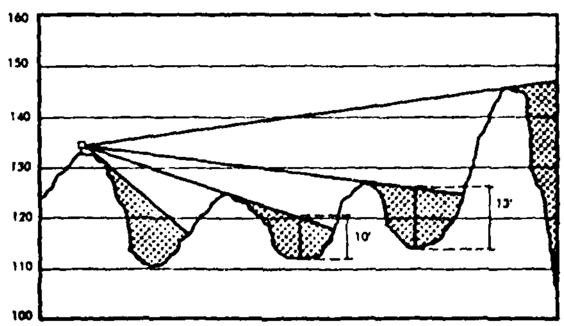


Figure 13. Defilade from profile.

When the defilade diagrams have been completed for a series of profiles, it is possible to produce a plot of masked areas by projecting lines from defilade boundaries to the contour map. An example of such a plot is shown in Figure 14.

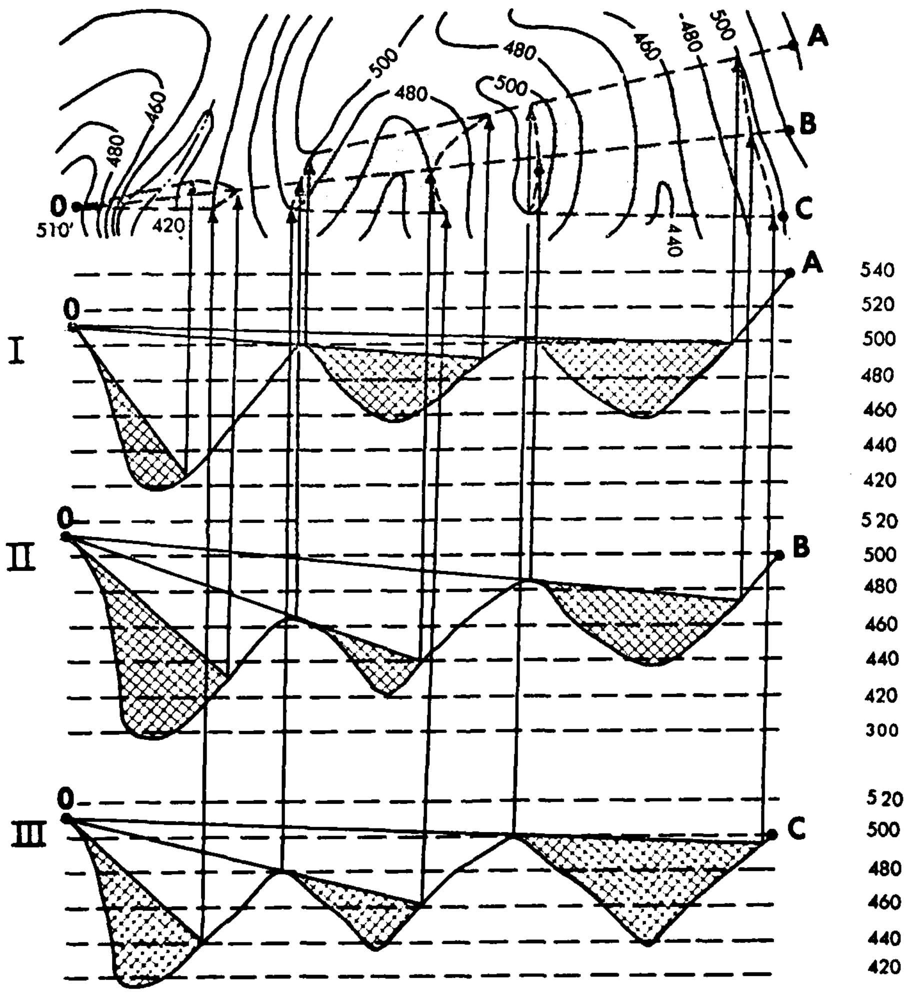


Figure 14. Plotting mask areas.

Computer-Generated Display Applications. The preceding section was provided to indicate the complexity of manually producing masking plots. Masking plots simply cannot be manually produced for extensive areas in

reasonable periods of time. Through a computer system, however, masking plots may be produced rapidly. All that is required of the aviator is that he enter the position of the observer or radar site on the display, and indicate the range of plot required (based on atmospheric attenuation, radar return limits, or other tactical considerations). The computer-generated topographic display can quickly produce a plot of the areas visible and not visible to an observer or radar at the designated position. An example of such a plot is shown in Figure 15.

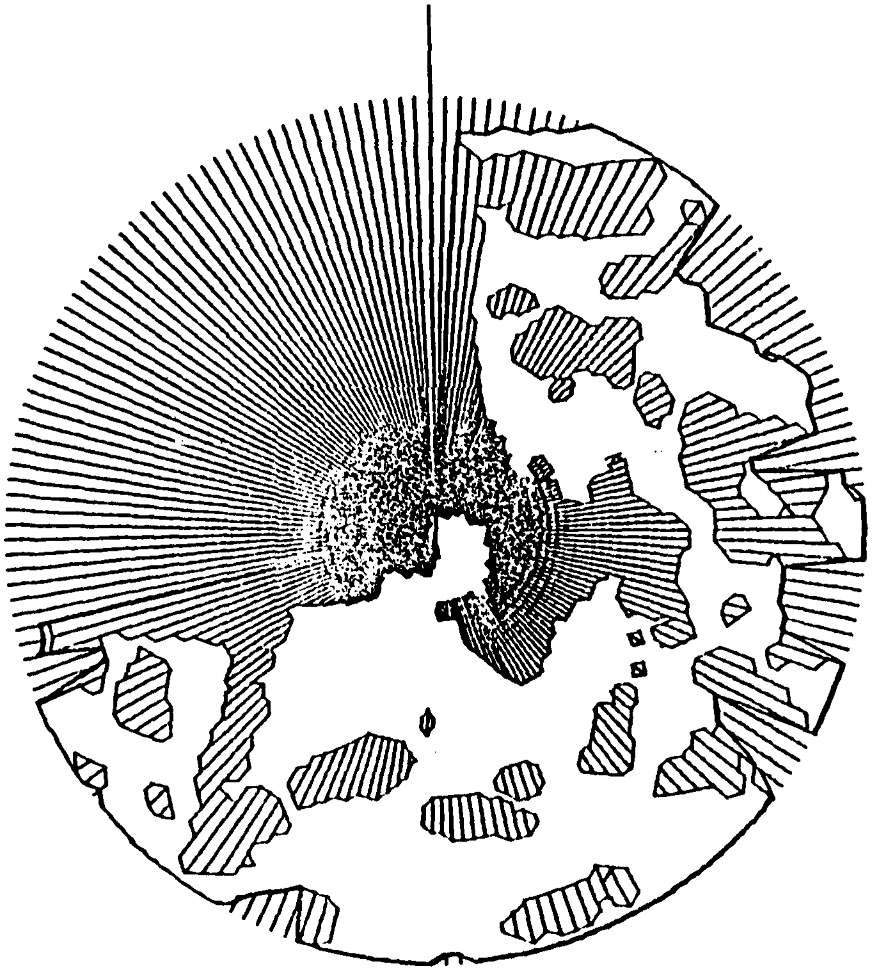


Figure 15. Computer-generated masking diagram. (Figure courtesy of ETL)

A number of enemy positions could be designated, if desired, to depict the likelihood of being observed given the actual battlefield situation.

Specific Applications of Computer-Generated Masking Plots

a. *Route selection.* Only in the simplest scenarious of combat situations are the optimal flight routes immediately obvious. The possible distributions of enemy-held positions, radar and weapon ranges, and landform shapes and elevations are innumerable. The determination of masked areas in many of these cases woulu be impossible within reasonable time periods without the aid of a computer-generated display system. The computer-generated topographic display can rapidly depict areas masked from enemy observation, given the known and suspected enemy positions. It remains only for the aviator to choose the most direct path to his objective through the masked areas, and to select the shortest paths between masked areas when brief exposures are unavoidable.

b. *Flight mode selection.* In addition to choosing the route of flight, the aviator must also determine the altitudes at which masked flight is possible. Low level flight is preferable to contour flight, and contour flight is preferable to NOE flight due to the greater safety and efficiency of flight at greater altitudes. The computer-generated topographic display is capable of calculating and depicting routes which provide maximum altitude above ground level, and indicating the maximum masked altitude in feet. As a result, the aviator can easily identify the portions of the route which may be flown in the low-level mode, and those which demand contour or NOE flight modes.

c. *Site selection.* The selection of specific positions for LZ's, rally points, pickup points, and firing positions also requires the determination of available masking to be sure that these sites are unlikely to be detected by the enemy. Assembly areas, holding areas, and FARRP's must be chosen with an appreciation of masked approach routes to prevent enemy detection of heavy activity. For these applications, the computer-generated topographic display may be employed in exactly the same way as for flight route selection.

d. *Fields-of-fire determinations.* Fields-of-fire must be understood both for enemy and friendly weapons. Fields-of-fire are determined primarily

by terrain contour and weapon range, although vegetation and cultural obstacles may be an influence. If the aviator enters a weapon location and range, the computer system can quite easily depict the fields-of-fire for those weapons. As a consequence, friendly weapon positioning may be planned for optimal area coverage, as in the selection of firing positions, and exposure to enemy fields-of-fire may be minimized.

e. *Checkpoint perceptibility.* In NOE flight, one of the most important determinants of checkpoint perceptibility is the vertical development of the checkpoint. Low-lying features, such as ponds, will not be seen unless the aircraft passes very near to them, while taller features, such as chimneys and powerline pylons may be seen from much greater distances. The masking computations of the computer-generated topographic display may be employed to determine whether a given checkpoint is likely to be visible from any point in the areas, and, for that point, specify the altitude from which the checkpoint would almost certainly be visible. When coupled with the aircraft masking computations, the risk of higher flight for aiding checkpoint detection would be made apparent.

D. NAVIGATION AND FLIGHT MANAGEMENT

A number of functions required of Army aviators are relatively routine flight management tasks undertaken as a part of flight planning and navigation. These functions are readily amenable to automation. The computer-generated topographic display can perform these tasks more readily and with fewer errors than they can be done using traditional methods, and can take certain influences of topography into account without difficulty. Such functions include the planning of flight legs, and the estimation of flight speeds, flight times, and fuel requirements.

In addition to aiding in these routine planning functions, the computer-generated topographic display can predict sun and moon positions, monitor the flight path for entry into danger zones, and provide special display modes. Perhaps the most valuable feature of the computer-generated system is its direct adaptability to the incorporation of terrain correlation technology. This technology identifies and indicates the aircraft's position on the topographic display with extraordinary accuracy, as described below.

FLIGHT LEG DATA

Discussion of Requirements. Once the general route of flight has been selected, the Army aviator normally annotates the map with turning points, or other air control points, and draws lines between them to define the legs of the flight, even if the actual flight path is a weaving one. The legs are then measured and their lengths recorded. A protractor is used to identify the grid bearings of the legs, which are converted to magnetic headings, and recorded with leg length. These steps must be performed correctly in order to continue with subsequent flight preparation functions.

Computer-Generated Display Applications. The preparation of flight leg data can be speeded and simplified by a computer-generated system. Once the aviator has designated the start point, turning point, and end point of the flight route and return route, all other tasks could be performed automatically.

The computer-generated topographic display would draw the lines between the points, display the magnetic headings and lengths of each of these legs, and store this data for use in subsequent computations.

SPEED ESTIMATES

Discussion of Requirements. Having determined the length of each leg from the staging area to the objective and return, the aviator considers several factors and attempts to determine reasonable airspeeds and groundspeeds for the flight legs. These factors include at least the following:

a. *Terrain.* The elevation of the flight path (above sea level) and the slopes which the path follows.

b. *Weather.* Flight may be conducted under restricted visibility conditions such as in rain and fog.

c. *Hour.* Flight may be conducted in low light levels, or in darkness using night-vision goggles.

d. *Mode.* To maintain masking, the flight may be conducted in low-level, contour, or NOE modes. When masking is unavailable, the "dash" mode will be employed.

e. *Aircraft.* Aircraft performance data given gross weight and other conditions.

f. *Mission.* The constraints of the mission may include some critical timing requirements for coordination.

g. *Wind.* Wind speed and direction must be used to convert airspeed estimates to groundspeed estimates.

Computer-Generated Display Applications. The factors listed above can influence speed requirements and capabilities in complex and interactive ways. The aviator is perfectly capable of making the appropriate analyses and decisions regarding airspeeds, but only at the cost of significant planning time which might be spent more effectively in tactical decision-making

and battle-area study. While extensive discussions of the computer algorithms that would aid in speed estimation is beyond the scope of this section, it is clear that models could be developed that would greatly unburden the aviator. The computer system would already "know" the flight route, so only a few other entries would be required of the aviator. The results of the calculations would be displayed, and stored for use in subsequent computations.

TIME ESTIMATES

Discussion of Requirements. The aviator must perform a series of elapsed time (et) and clock time (ct) estimates for navigation and flight management, as follows:

a. *Objective arrival time (ct).* The mission engagement point arrival time may be given in the operations order.

b. *Checkpoint times (ct and et).* Enroute times for each leg of the flight and between each adjacent checkpoint pair must be calculated using the previous airspeed and distance computations.

c. *Enroute time (et).* The total time from the staging area to the objective is determined by adding checkpoint times.

d. *Departure time (ct).* The time to depart the staging area is determined by subtracting the enroute time from the objective arrival time.

e. *Mission time (et).* The time required (or allowed) to perform the mission at the objective may be included in the operations order, or may be estimated by the aviator.

f. *Return time (et).* The total time from the objective to the staging area is determined by adding the checkpoint times.

g. *Total flight time (et).* The total time from departure to return is found by adding the enroute, mission, and return times.

h. Flight termination time (ct). The clock time of return to the staging area is found by adding the total flight time to the departure time.

AD-A091 240 ANACAPA SCIENCES INC SANTA BARBARA CA F/G 8/2
TOPOGRAPHIC INFORMATION REQUIREMENTS AND COMPUTER-GRAPHIC DISPL--ETC(U)
DEC 79 S P ROGERS, K D CROSS DAHC19-78-C-0012
UNCLASSIFIED AS-365-79 USAAVRADCOM-TR-78-0012-F NL

2 of 2

END
DATE
FILMED
12-80
DTIC

Computer-Generated Display Applications. The elapsed time and clock time estimates listed above are not difficult for the aviator to make. However, the computer system can perform them in milliseconds with a near-zero probability of error. The aviator needs only to enter the objective arrival time and the mission time. All other times would be calculated and displayed in a fraction of a second, since the computer system would have previously stored the flight leg and speed data. The rapidity of these calculations becomes especially important when one or more of the times must be changed and the remaining ones re-estimated--a situation very likely to occur during flight. The time estimates are displayed upon request, and are stored for subsequent calculations.

FUEL REQUIREMENTS

Discussion of Requirements. The aviator must determine the fuel requirements for each flight. Long flights may require that the tanks be "topped off," but full tanks reduce the aircraft's maneuverability and load-carrying capacity, and may not always be advisable. The minimum required fuel and the maximum allowable fuel may be computed by considering at least the following:

1. Gross weight.
2. Aircraft performance data.
3. Flight distance.
4. Flight altitude(s).
5. Airspeed(s).
6. Wind speed and direction.
7. Total flight time.

Computer-Generated Display Applications. As in the cases of speed and time estimates, fuel requirements can certainly be determined by Army aviators without computer assistance--but only at the cost of significant planning time and occasional errors. The computer-based system would already have all of the required information except gross weight and flight altitudes, so minimum required and maximum allowable fuel could be calculated in moments, and recalculated with equal rapidity if changes are made in any of the pertinent variables before or during the flight.

SUN AND MOON POSITION

Discussion of Requirements. For thousands of years an important combat tactic has been the placement of the opponent at a disadvantage with respect to the sun. When the sun or moon is positioned in the central portion of the field of view, the resulting glare causes discomfort and decreases visibility. It follows that one of the aspects of good preflight planning is the consideration of sun or moon position--both the azimuth, and the angular distance above the horizon.

Computer-Generated Display Applications. A minor subroutine incorporated in the software of the computer-generated topographic display would make sun and moon position-findings possible. The aviator would have only to enter the time and date of the anticipated flight for the computer system to provide him with the exact sun or moon azimuth and angular elevation at the local geographic area.

MONITOR AND ALARM

Discussion of Requirements. One of the uses of the annotated topographic map is to serve as an indicator of danger zones. Such danger zones include, for example, areas and altitudes in which the aircraft is not masked from enemy observation, NBC-contaminated areas, and artillery air corridors within which all aircraft will receive fire. The standard topographic map, when properly annotated provides a passive warning system. The annotations must be clear, and the aviator must observe them in order for them to be effective.

Computer-Generated Display Applications. The computer-generated topographic display could offer an active system, continuously monitoring the position of the aircraft with respect to the danger zones, even when these zones are not being depicted on the display. If the aircraft position is sensed crossing a danger-zone boundary or rising above a masked altitude, the aviator could be alerted by a warning tone and flashing of the critical information on the display screen.

TOPOGRAPHIC DISPLAY MODES

Discussion of Requirements. Airborne map displays have existed in one form or another for many years. Depending upon the types of maps, missions, and aircraft, different design criteria have been applied to the display system features. As a result, numerous modes of operation have been developed and found to be useful in navigation and flight management. Since they were primarily developed for high-performance fixed-wing aircraft, their utility must be re-evaluated in the context of helicopter operations. These modes are listed here not as definitive requirements, but as features found useful in other circumstances, deserving consideration for helicopter use.

a. *Azimuth stabilized display.* As the aircraft turns, the display remains oriented in one direction. Although the display can be stabilized at any orientation, this mode is usually referred to as "north up."

b. *Course stabilized display.* As the aircraft turns, the display rotates to show heading up.

c. *Track stabilized display.* As the aircraft turns or drifts, the display rotates to show wind-corrected course up.

d. *Aircraft-position centered display.* The display moves with respect to an aircraft-position symbol which is fixed in the center of the display. This mode can be combined with any of the display-orientation features described above.

e. *Decentered display.* The display moves with respect to an aircraft-position symbol which is fixed at a point between the bottom and the center of the display. This mode may also be accompanied by any of the display-orientation features described above.

f. *Destination centered display.* The display is fixed, usually north up, and centered on a waypoint, destination, or target that has been programmed in the computer. In a moving-symbol display, the aircraft-position symbol moves with respect to the fixed map. In a moving map display, the aircraft-position symbol no longer represents the position of the aircraft, but is an index demarking the position of the programmed destination.

g. *Quickened display.* The displayed aircraft position indicates the position that will be achieved, under prevailing flight conditions, at a given number of minutes hence. This mode can be provided only in electronic map displays.

h. *Standby, hold, or freeze mode.* The displayed information maintains its present status, while the computer calculates and stores changes in that status.

i. *Alignment, calibration, or updating mode.* Corrective information is entered into and accepted by the computer; initial fiducial references are entered.

j. *Test mode.* Built-in or programmed tests are made to check the functioning of the display.

k. *Manual mode.* The display is slewed by a manually operated controller rather than by the computer.

l. *Supplementary data display.* Information other than the navigation chart, such as checklists, procedures, or airways information, is shown on the display face.

Computer-Generated Display Applications. It is quite likely that several of the display modes listed above will be shown to be of great value for NOE flight use.

The computer-generated topographic display is capable of implementation with any of the flight display modes employed to date, and can quickly switch between them or combine them to meet momentary requirements. Further research will be required to prioritize the features for inclusion in the computer-generated topographic display, and it is possible that new, more valuable features will be developed in light of the tremendous flexibility offered by a computerized system.

AUTOMATED ORIENTATION

Discussion of Requirements. Systems for automatically determining and displaying aircraft geographic position have been intensively studied for many

years, and improvements have been continuously forthcoming. Many electronic navigation systems have been developed to support combat aircraft. These systems have typically employed three subsystems: navigation sensors, navigation computer, and navigation display. The sensors have most often been doppler radar for velocity data, inertial guidance systems for heading information, and ground-based aids for sensing supplementary position information. Compass and indicated airspeed data have also been used as computer inputs. Display systems have included numeric information, roller maps, and projected map displays. It is somewhat ironic that these electronic navigation systems have all been designed for high-flying fixed-wing aircraft, while clearly such a system is most urgently needed for use in the low-flying helicopter. There is no more difficult aircraft navigation task than that posed by NOE flight.

Computer-Generated Display Applications. The computer-generated topographic display is perfectly compatible with the most recent development in automated navigation--terrain correlation technology, such as that employed in the "cruise missile" weapons. One form of terrain correlation system is known as the Kalman filter navigation system, which uses the difference between a predicted ground clearance, based on stored topographic data, and a radar altimeter-derived ground clearance to continuously update the navigation display. Other, similar systems perform their computations in slightly different ways. The advantages of such systems are that they are relatively small and lightweight, they are accurate in all weather, they are self-contained, they are accurate regardless of flight time and distance, and they are essentially invulnerable to electronic countermeasures. The terrain-correlation technology, in conjunction with the computer-generated topographic display may be used to graphically present the aircraft's exact geographic position at all times. The long-awaited "black-boxing" of the geographic orientation task may soon become a reality for those who need it most--NOE aviators.

REFERENCES

Cross, K. D. *Memorandum on the utility of a computer-generated topographic display.* Santa Barbara, California: Anacapa Sciences, Inc., April 1977.

Gainer, C. A., & Sullivan, D. J. *Aircrew training requirements for nap-of-the-earth flight.* Santa Barbara, California: Anacapa Sciences, Inc., May 1974.

Garlichs, E. A., Cox, R., Hockenberger, R. L., & Smith, B. A. *Tactical permission planning.* Fort Rucker, Alabama: Canyon Research Group/ Army Research Institute, June 1979 (draft edition).

McGrath, J. J., & Osterhoff, W. E. *Geographic orientation in aircraft pilots: Validation of an analysis of visual checkpoints.* Goleta, California: Human Factors Research, Inc., July 1969.

Rogers, S. P., & Cross, K. D. *Accuracy of geographic orientation during nap-of-the-earth flight as a function of topographic map contour-line interval.* Santa Barbara, California: Anacapa Sciences, Inc., December 1978.

Sanders, M. G., Simmons, R. R., & Hofmann, M. A. Visual workload of the copilot/navigator during terrain flight. *Human Factors,* 1979, *21,* 369-383.

U. S. Army. *FM 1-1, Terrain flying.* October 1976.

U. S. Army. *FM 17-50, Attack helicopter operations.* July 1977.

U. S. Army. *FM 90-1, Employment of aviation units in a high threat environment.* September 1976.